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CONTAINING

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. NOVEMBER 10, 1899. No. 1

Professor G. H. DARWIN, M.A., LL.D., F.R.S., PRESIDENT, in the Chair.

Rev. Thomas Gerrard Barber, B.A., 10 Highfield Road, Doncaster; and
Sydney Samuel Hough, M.A., Royal Observatory, Cape of Good Hope,

were balloted for and duly elected Fellows of the Society.

George E. Hale, D.Sc., F.R.A.S., Director of the Yerkes Observatory, Williams Bay, Wisconsin, U.S.A.;
F. R. Helmert, Director of the Royal Geodetic Institute, Potsdam, Germany;
F. Küstner, Director of the Observatory, Bonn, Germany; and
Juan M. Thome, Director of the Argentine National Observatory, Cordoba, Argentine Republic,

were balloted for and duly elected Associates of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Professor R. N. Apte, M.A., LL.B., Rajaram College, Kolhapur, India (proposed by Sir R. S. Ball);
Maurice Harvey Clarke, Lieut. R.N.R., F.R.G.S, Woodlands, Ashburton Road, Croydon (proposed by Capt. P. Thompson);

Rev. P. W. Fairclough, Wesleyan Minister, Kaiapoi, New Zealand (proposed by Rev. D. Dutton);

Umes Chandra Ghosh, M.A., Lecturer on Mathematics, Muir Central College, Allahabad, India (proposed by Asutosh Mukhopadhyay);

Richard Kilvington Hattersley, 4 Church Terrace, Blackheath, S.E. (proposed by Capt. P. Thompson); and

Howard Payn, F.R.G.S., Barrister-at-Law, 21 Hyde Park Place, London, W. (proposed by W. J. S. Lockyer).

Two hundred and eleven presents were announced as having been received since the last meeting, including amongst others :—

British Astronomical Association, The Indian Eclipse, 1898, presented by the Association; Cape Observatory, Catalogue of 3007 stars for 1890·0, from observations made during 1885–95, presented by the Observatory; A. M. W. Downing, Precession Tables adapted to Newcomb's constant of precession, and reduced to the Epoch 1910·0, presented by the Author; Harvard Observatory, Annals, vol. 23, part 2, Discussion of observations made with the meridian photometer, presented by the Observatory; E. Lebon, Histoire abrégée de l'Astronomie, presented by the Author; Lick Observatory, Series of Photographs of nebulæ made with the Crossley reflector, and photographs of the solar eclipse of 1898, &c., presented by the Observatory; Madrid Observatory, Maps showing tracks of total solar eclipses 1900 and 1905, presented by Señor Ventósa; D. P. Todd and W. T. Lynn, Stars and Telescopes, presented by W. T. Lynn; Washington Ephemeris Papers, vol. 8, pt. 2; S. Newcomb, Catalogue of Fundamental Stars for 1875 and 1900, reduced to an absolute system, presented by the Ephemeris Office; L. Weinek, Photographischer Mond-Atlas, Heft 6, presented by L. Weinek.

Preliminary Note on the Spectrum of a Aurigæ.
By H. F. Newall, M.A.

One of the first results obtained with the four-prism spectroscope which has lately been attached to the 25-inch equatorial of the Cambridge Observatory, is the discovery that the star *a Aurigæ* is one of the class which is known under the name of spectroscopic binary. Precise details will be published as soon as possible.

[NOTE.—Since the above was written the *Astrophysical Journal* for October has arrived in this country, and I find that Prof. Campbell of the Lick Observatory has published a similar announcement (vol. x. p. 177).]

On the Variation of Personal Equation with Stellar Magnitude in Observations made at Cambridge, Berlin, and Greenwich; as deduced from Measures of Photographic Plates taken at Oxford. By H. H. Turner, M.A., F.R.S., Savilian Professor.

The belt of the heavens now being photographed at the University Observatory, Oxford (zones $+25°$ to $+31°$) as part of the work of the Astrographic Chart, includes the belt observed on the meridian at the Cambridge Observatory ($+25°$ to $+30°$) during the years 1872 to 1896, as part of the revision of the D.M. according to the scheme of the *Astronomische Gesellschaft.* The places of the Cambridge Catalogue (epoch 1875·0) brought up to 1900·0 are compared with the Oxford measures to get the plate-constants; and when these have been deduced residuals are formed showing the corrections to the Cambridge places given by the Oxford measures, and are entered in ledgers.

2. There is no 'vicious circle' in first using the Cambridge places to find the Oxford plate-constants, and then using the Oxford measures corrected by these plate-constants to find the errors of individual stars in the Cambridge Catalogue; for there are many more Cambridge stars on the plate than are necessary to determine the plate-constants, for which 3 stars would suffice. There are nearly always 20 Cambridge stars on the plate, and sometimes as many as 100; and we are really finding the individual corrections for each star referred to the mean of the 20 or of the 100; just as if we observe 20 clock-stars we may determine the clock-error from the mean of them, and, using this, find the corrections to the individual assumed places.

3. The Ledgers of Corrections to Cambridge places then give us quantities made up of

(A) Proper motions between the epoch of observation at Cambridge, and the date of the plate taken at Oxford (about 1895 say).

(B) Systematic errors of the Oxford measures.

(C) Systematic Errors of the Cambridge Catalogue.

4. The present paper deals with an error which falls under head (C), viz., the variation in personal equation at Cambridge with stellar magnitude. The Oxford measures are freed from this error; for, after measuring each plate, it is rotated 180° in its own plane and re-measured. The mean of the two measures is freed from any personality or error of bisection.

[Moreover, the differences of the two measures indicates the amount of this personality, and it is not found to vary sensibly with stellar magnitude. But this is immaterial for our present purpose.]

5. Though the Ledger residuals are affected by other quantities under head (A) or (B), these may be regarded as accidental errors in the present discussion, which will disappear in the

mean of a number of stars; and to determine the variation of personal equation with stellar magnitude at Cambridge we have little more to do than to group the residuals according to stellar magnitude and take the means of groups. A preliminary discussion was given by Mr. A. R. Hinks in 1897 (*Monthly Notices*, lvii. p. 473), but when only 7 Oxford plates had been measured. Now more than 600 plates have been measured and reduced, and it is possible to give something like a definitive character to the investigation. The matter is so important that it will no doubt be interesting to give the final results deduced from the whole 1180 plates forming the Oxford share of the work; but at the same time the quantities found are so large, and are so clearly indicated by the material already available, that it seems advisable to publish the following results at once:—

Comparison between Oxford Photographic Measures and Cambridge Transit-Circle Observations.

The sign + indicates that the Cambridge R.A. or Decl. is too small.

Mag. (Cambr.)	No. of Stars.	Corrections to Cambridge R.A.			Decl.
		O	C	O–C.	
		s	s	s	″
1·0 to 2·9	4	+·118	(+·204)	(–·086)	–0·12
3·0 to 3·9	7	+·113	(+·170)	–·057	+0·18
4·0 to 4·9	9	+·180	(+·147)	+·033	–0·39
5·0 to 5·4	38	+·131	+·129	+·002	–0·21
5·5 to 5·9	30	+·114	+·118	–·004	–0·30
6·0 to 6·4	88	+·104	+·106	–·002	–0·30
6·5 to 6·9	147	+·093	+·095	–·002	–0·27
7·0 to 7·4	320	+·084	+·083	+·001	–0·33
7·5 to 7·9	504	+·071	+·072	–·001	–0·12
8·0 to 8·4	572	+·050	+·060	–·010	–0·15
8·5 to 8·9	1226	+·023	+·022	+·001	–0·06
9·0 to 9·4	2001	–·037	–·030	–·007	+0·13
9·5 and over	438	–·066	–·070	+·004	+0·26

Column I. gives the magnitudes from the Cambridge Catalogue, Column II. the number of stars. To mag. 7·9 this is practically the total number as yet photographically observed at Oxford in all R.A.'s, but for magnitudes 8·0 to 9·5 and over only the hours 0^h—12^h R.A. have as yet been discussed. For reasons given later it is believed that the general mean would not be altered by including the whole of the faint stars, and as the present discussion is not final the additional labour has not been undertaken.

In Column III. is given the mean photographic correction to the Cambridge R.A. For the first three groups the number of

stars is so small that the results must not be treated too seriously. Proper motions have been applied (taken from the Greenwich Catalogue 1880·0) for the interval between the Cambridge and Oxford observations, though in the other groups P.M. has been treated as accidental error.

Moreover, most of the Cambridge places for these stars do not represent actual observations, but are simply copied from Auwers' *Fundamental Catalog.* They are only Cambridge observations in this sense, that the clock-errors were derived by comparing Cambridge observations of such bright stars with the places of the *Fundamental Catalog*, so that the mean bright star of the *Fundamental Catalog* must agree with its Cambridge R.A. Of course the individual stars may show discordances, but from the comparison with Greenwich given below it seems possible that these places may be regarded sensibly as Cambridge places even for individual stars.

In Column IV. is given a theoretical correction representing the observed residuals, viz. :—

For the brighter stars to magnitude 8·0

$$\text{Correction} = +0^{s}{\cdot}25 - 0^{s}{\cdot}023 \times \text{magnitude}.$$

About magnitude 8·0 the gradient changes as indicated in the diagram, and for the fainter stars we may write

$$\text{Correction} = +0^{s}{\cdot}89 - 0^{s}{\cdot}100 \times \text{magnitude}.$$

A hyperbola would thus well represent the observations, but it seems needless to derive a more exact empirical formula.

In Column V. are shown the differences between the curve of the diagram and the observed quantities.

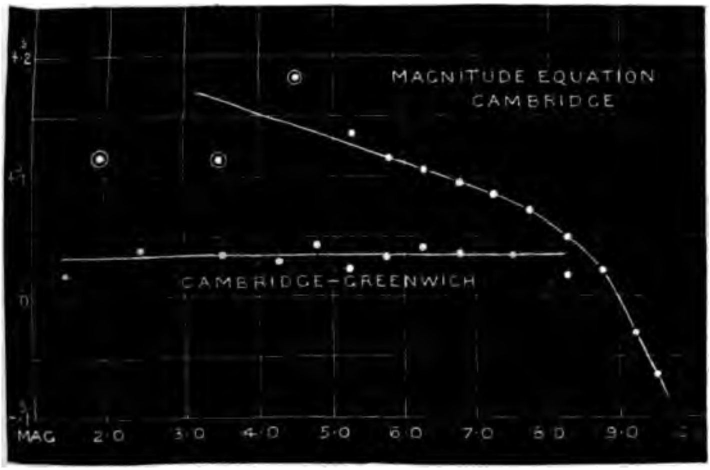


Diagram representing Variation of Personal Equation with Stellar Magnitude in Cambridge Meridian Observations.

In Column VI. are given similar results for declination, showing that in declination there is no serious personality depending on magnitude until we reach faint stars.

Up to magnitude 8·0 the declinations are consistent with the photographic measures, neglecting the first three groups, which are not really Cambridge observations. But about magnitude 8·0 a change begins, which becomes emphatic for stars of magnitude 9·5 and over.

6. It is clear that if we would use the Cambridge meridian places to the best advantage in finding the "constants of our plates" we must apply to them :—

(*a*) Differential corrections depending on magnitude ; for there is a systematic error ranging over about $0^s·15$, even between magnitudes 8·0 and the faintest stars. On any single plate there are not likely to be more than one or two stars brighter than 8·0, but the differential correction among the more numerous faint stars is still serious.

(*b*) We must apply a considerable index error, or constant correction, to all the R.A.'s and declinations, if we wish them to be comparable with meridian observations of bright stars—say stars of the sixth magnitude. And here we are, of course, met by the difficulty of adopting a fixed standard. What observations shall we take as our starting-point?

7. A necessary preliminary to answering this question is to determine how the Cambridge observations accord with other catalogues. Mr. Hinks has given, in the paper above referred to, a comparison of Cambridge and Berlin R.A.'s, based on the common zone $+24° 50'$ to $+25° 10'$, which is practically as follows :—

Mean Mag.	Camb. R.A. —Berlin R.A.	Oxford (phot.) —Camb.	Oxford (phot.) —Berlin.
	s	s	s
6·5?	+ ·003	+ ·100	+ ·103
7·5	+ ·018	+ ·078	+ ·096
8·5	+ ·056	+ ·036	+ ·092
9·5?	+ ·093	− ·060	+ ·033

Dr. Becker's result (obtained from observations with screens which diminished the light of the star by a known amount) that his R.A.'s required correction by $-0^s·007$ per magnitude is thus confirmed fairly well by the first three groups. If the Berlin R.A.'s of 7·5 magnitude stars were diminished by $0^s·007$, of 8·5 magnitude by $0^s·014$, and of 9·5 magnitude by $0^s·021$, the differences in the fourth column above become

Mean Mag.	Oxford photog. —Berlin corrected.
	s
6·5?	+ ·103
7·5	+ ·103
8·5	+ ·106
9·5?	+ ·054

But there is a drop for the faint stars. Probably Dr. Becker did not push his observations far enough as regards the fainter stars. There is nothing to negative this conclusion in the summary of his observations given in the introduction to the Berlin Catalogue.

8. It thus appears that as regards the fainter stars the variation of personal equation is different for different observers. A more hopeful result, however, was obtained for the brighter stars on comparing Cambridge and Greenwich. The Greenwich Ten-Year Catalogue (1880) was compared with the Cambridge Catalogue (1875), with the following result :—

R.A. (Cambridge) — R.A. (Greenwich)			
Mag.	No. of Stars.	Mean Difference.	Excess over +0ˢ·035.
		s	s
1·0 to 1·9	2	+ ·020	−0·015
2·0 to 2·9	3	+ ·040	+ ·005
3·0 to 3·9	10	+ ·036	+ ·001
4·0 to 4·4	12	+ ·029	− ·006
4·5 to 4·9	27	+ ·043	+ ·008
5·0 to 5·4	31	+ ·021	− ·014
5·5 to 5·9	60	+ ·033	− ·002
6·0 to 6·4	33	+ ·043	+ ·008
6·5 to 6·9	19	+ ·036	+ ·001
7·0 to 7·9	19	+ ·034	− ·001
8·0 and over	7	+0·019	− ·016

Whence it would appear that the variation of personality with magnitude as far as magnitude 8·0 is sensibly the same at Cambridge as at Greenwich; that is, bright stars are observed both at Cambridge and Greenwich relatively too early by 0ˢ·023 per magnitude.

9. Now this result is in satisfactory agreement with the results of experiments made with screens at Greenwich about 1891 (see a paper by the Astronomer Royal : *Preliminary Note on change of Personal Equation with Stellar Magnitude in Transits observed with the Transit Circle at the Royal Observatory, Greenwich*, *Monthly Notices*, vol. li. p. 455). The transit of a star when its apparent magnitude was diminished by covering the object-glass with a screen, was found to be recorded later by the following quantities (p. 458) :—

	s
Screen *a*	+0·031
Screen *b*	+0·026
Screen *c*	+0·035
Mean	+0·031

But it was found rather difficult to estimate the photometric value of the screen. "We may say . . . . that the screens *a*, *b*, and *c* each diminish the brightness by between 1·5 and 2·0 magnitudes," is the cautious conclusion arrived at (p. 456). Thus the change of personal equation per magnitude lies between 0^s·021 and 0^s·016. The value of this quantity found in the present paper (0^s 023) slightly exceeds the former limit, but there is no serious discrepancy between the results; and when the difficulties of the "screen" method are considered, we cannot but feel that the results arrived at by its use, both at Berlin and at Greenwich, are surprisingly good.

10. Let us glance for a moment at the sort of systematic error this implies, for instance, in the Greenwich clock-star list. The mean magnitude of the stars in the list is about 3·8; and the mean excess of magnitude for each hour of the twenty-four is shown below, with the corresponding correction to the mean hourly R.A., on the assumption of a systematic error of 0^s·023 per magnitude:—

Hour.	Excess of Mag.	Correction. s	Hour.	Excess of Mag.	Correction. s	Hour.	Excess of Mag.	Correction. s
0–1	+0·3	−·007	8–9	+0·6	−·014	16–17	−0·7	+·016
1–2	−0·1	+·002	9–10	+0·5	−·012	17–18	−0·3	+·007
2–3	+0·3	−·007	10–11	+0·5	−·012	18–19	−0·3	+·007
3–4	+0·5	−·012	11–12	0·0	·000	19–20	+0·3	−·007
4–5	−0·1	+·002	12–13	+0·3	−·007	20–21	+0·4	−·009
5–6	−1·5	+·030	13–14	0·0	·000	21–22	0·0	·000
6–7	−0·4	+·009	14–15	+0·2	−·005	22–23	−0·2	+·005
7–8	−0·8	+·018	15–16	+0·1	−·002	23–24	+0·6	−·014

Of course, so long as the habits of the observers remain much the same, and the clock-star list is not altered, these systematic errors do not appear. We may replace the bright stars (taking faint stars as standard) by fictitious stars of slightly less R.A., and consider the observations always made on the fictitious stars. How far the habits of observers remain constant is yet to be determined. There is a good deal of straightforward work ready for anyone who will undertake it in the comparison of catalogues according to magnitude. I must confess that the above comparison of Cambridge and Greenwich, and the similarity of habit thereby indicated, came as a surprise to me when I found how large the magnitude equation at Cambridge was. I quite expected a different magnitude equation at Greenwich, if only because the chronographic method is used, instead of the eye-and-ear method as at Cambridge. If this personality turns out to be even approximately the same at a number of observatories it will be something to be thankful for.

As regards the clock-star list, it has been much extended since Pond's days. Are some of the systematic errors of his list,

hitherto supposed to have arisen from his observing too short groups of clock-stars, really due in part to this magnitude personality? The quantities given in the above table are in some respects not unlike those shown in the Introduction to the Nine-Year Catalogue (1872·0).

11. Returning to the actual Cambridge personality, one important question is—Does it vary with R.A.? The answer seems to be in the affirmative; but the variation is small compared with the whole amount. It is also rather exceptional in character; and as yet I can suggest no physical reason for it. The personality is rather greater for 21^h–3^h R.A. and for 12^h–15^h R.A. than for the rest of the circuit, and is greater proportionately, *i.e.* the increase is greatest for bright stars.

12. Before giving the numbers which seem to show this we must remove a source of error. The residuals which are here under discussion represent the differences between individual stars and the mean star on each plate. Now the magnitude of this mean star varies; for the whole Cambridge Catalogue it has the following values:—

Mean Magnitude of Stars in the Cambridge Catalogue.

R.A.							
0^h–3^h.	3^h–6^h.	6^h–9^h.	9^h–12^h.	12^h–15^h.	15^h–18^h.	18^h–21^h.	21^h–0^h.
8·84	8·75	8·82	8·79	8·70	8·84	9·00	8·92

and we must accordingly apply to the three-hour groups of individual stars the following corrections:—

$-0^s{\cdot}001$ $+0^s{\cdot}006$ $0^s{\cdot}000$ $+0^s{\cdot}003$ $+0^s{\cdot}010$ $-0^s{\cdot}001$ $+0^s{\cdot}013$ $-0^s{\cdot}007$

which have been applied in what follows.

13. Collecting, then, the residuals into three-hour groups, we get the following differences from the mean for that particular magnitude:—

Mag.	R.A. 0^h–3^h. s	3^h–6^h. s	6^h–9^h. s	9^h–12^h. s	12^h–15^h. s	15^h–18^h. s	18^h–21^h. s	21^h–0^h. s
5·0 to 6·9	+·030	–·005	–·015	–·013	+·010	–·005	–·024	+·011
7·0 to 7·9	+·021	–·014	+·004	–·006	+·008	–·019	–·006	+·004
8·0 to 8·4	+·010	–·003	·000	+·001	...	...	...	...
8·5 to 8·9	+·006	+·004	·000	–·004	...	...	...	...
9·0 to 9·4	–·010	+·006	–·002	+·007	...	...	...	...

Beyond magnitude 7·9 the analysis has only been carried as far as 12^h; but it is clear that the discrepancy is greatest for the brightest stars.

This is perhaps more obvious in the following short table:—

Mag.	Mean Excess.	
	0^h-3^h over 3^h-12^h.	12^h-15^h and 21^h to 0^h over 15^h-21^h.
	s	s
5·0 to 6·9	+·041	+·025
7·0 to 7·9	+·026	+·019
8·0 to 8·4	+·011	...
8·5 to 8·9	+·006	...
9.0 to 9·4	−·014	...

The point requires further examination, but it seems well to draw attention to it.

14. When all the Oxford plates are measured groups will be formed for each tenth of a magnitude. This has been done to a considerable extent at present, but nothing important is thereby added to the main results above given. Up to magnitude 8·0 the stars are not numerous enough; the accidental errors merely mask the general form of the curve. Beyond 8·0 the groups for each tenth show rather more clearly the transition from the gradient for bright stars to that for faint stars. As remarked above, only the first 12^h of R.A. have yet been examined. The results are given below for magnitudes 7·0 to 9·5 :—

Mag.	No. Stars.	Personality.	Mag.	No. Stars.	Personality.	Mag.	No. Stars.	Personality.
		s			s			s
7·0	131	+·101	7·9	78	+·051	8·8	244	+·015
7·1	30	+·097	8·0	139	+·057	8·9	331	+·013
7·2	56	+·084	8·1	79	+·046	9·0	710	−·005
7·3	55	+·066	8·2	109	+·059	9·1	388	−·033
7·4	48	+·048	8·3	108	+·044	9·2	292	−·057
7·5	156	+·073	8·4	137	+·042	9·3	321	−·062
7·6	64	+·095	8·5	250	+·040	9·4	290	−·079
7·7	95	+·066	8·6	164	+·020	9·5	438	−·066
7·8	111	+·075	8·7	237	+·026			

Summary.

1. The Cambridge meridian observations show a distinct systematic "magnitude equation" or personality depending on the brightness of the star.

2. In R.A. this may be described by saying that to magnitude 8·0 or thereabouts bright stars are observed too early, by $0^s{\cdot}023$ per magnitude. For stars fainter than 8·0 the personality increases rapidly to $0^s{\cdot}100$ per magnitude.

3. In declination the personality does not appear till about magnitude 7·5; stars fainter than this are observed too far south.

4. Comparison with Berlin observations shows that the magnitude-equation determined by Dr. Becker from observations

with screens ($0^{\mathrm{s}}\cdot007$ per magnitude) is confirmed, except that this law changes for stars fainter than 8·5, which he perhaps did not sufficiently observe with the screens.

5. Comparison with Greenwich observations shows that the magnitude-equations at Cambridge and Greenwich are sensibly the same to magnitude 8·0—a result in fair accordance with observations made at Greenwich with screens in 1891.

6. The magnitude-equation at Cambridge is sensibly greater for stars of R.A.'s 21^{h}–3^{h} and 12^{h}–15^{h} than for stars in R.A.'s 3^{h}–12^{h} and 15^{h}–21^{h}.

Note added 1899 November 10: Since writing the above paper I have this morning seen the Cape Catalogue for 1890, just published, in the introduction to which Dr. Gill compares the catalogue according to stellar magnitude with other catalogues, and concludes that "these facts prove :—

"(1) The reality of the corrections derived by Auwers.

"(2) That the average observer is affected by a fairly constant personal error depending on magnitude.

"(3) The efficiency of the screen method for determining this error."

The first point is amply confirmed by the results of the present paper.

No. (2) confirms and extends the conclusion arrived at in the present paper by a comparison of the Cambridge (1875) and Greenwich (1880) Catalogues: that the magnitude-equation is often (perhaps generally) the same for different observers so far as magnitude 8·0 or thereabouts.

But with regard to (3) I think the present paper shows that :—

(A) Photographic measures give a much better method for determining the magnitude-equation.

(B) The screen method is liable to under-estimate the amount of the equation. Dr. Gill finds it by the screen method to be $0^{\mathrm{s}}\cdot014$ per magnitude. We have found above that it is $0^{\mathrm{s}}\cdot023$ for Greenwich, and so probably for the Cape also. The "screen" method used at Greenwich and Berlin gave similarly a small coefficient. The difficulty is in estimating the photometric value of the screen. The screens used at Greenwich were originally supposed to represent two magnitudes; and if that were so the resulting effect on observations of R.A. $0^{\mathrm{s}}\cdot031$ represents $0^{\mathrm{s}}\cdot016$ per magnitude, which is sensibly Dr. Gill's result. But during the actual observations at Greenwich reasons were found for suspecting this assumed photometric value; and this is expressed in the Astronomer Royal's paper by the cautious conclusion above quoted: "We may say that the screens *a*, *b*, and *c* each diminish the brightness by between 1·5 and 2·0 magnitudes." It would seem that even the lower limit is not quite low enough. The result $0^{\mathrm{s}}\cdot031$ corresponds to 1·3 magnitudes as the photometric value of the screen; and it would seem that the

observations made rather determine this photometric value than the amount of the magnitude-equation. Dr. Gill has begun measuring star photographs with a very accurate micrometer. I cannot help thinking that if he will take a few plates near the equator, and measure them for comparison with his meridian observations, he will quickly and easily determine the magnitude-equation and find reason to revise his opinion of the value of the "screen" method. In any case the independent check would be very valuable.

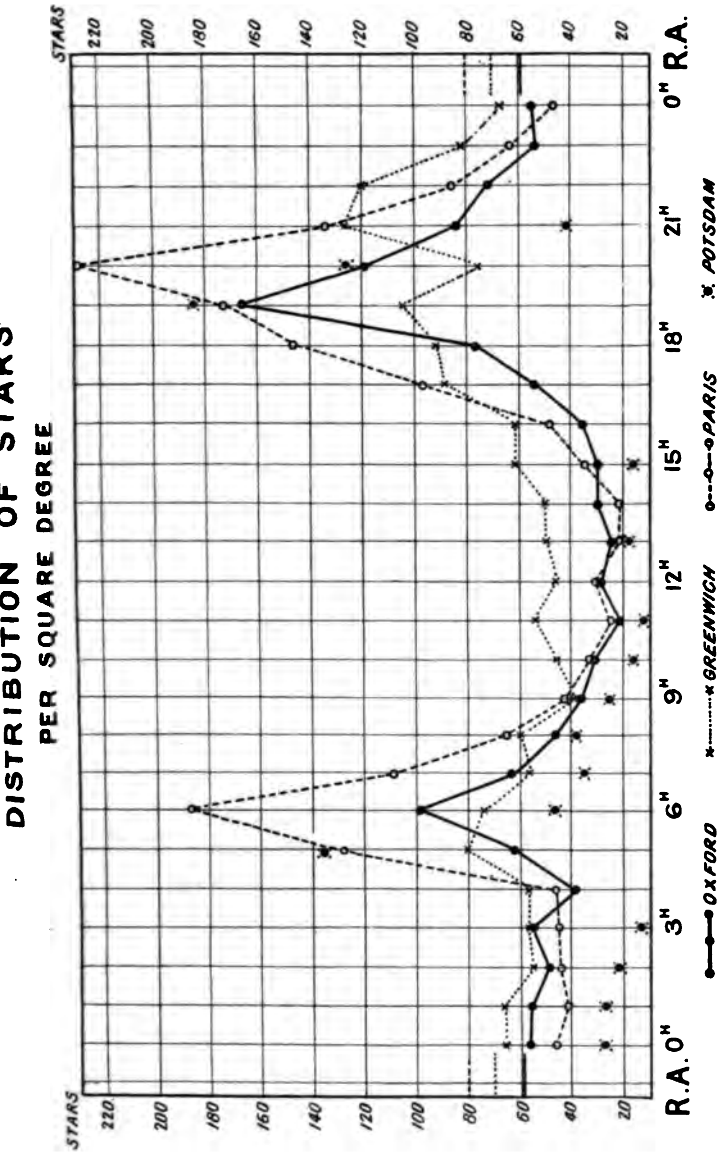
On the Distribution of Stars Photographed at the University Observatory, Oxford, for the Astrographic Catalogue for Zones $+25°$ to $+29°$. By F. A. Bellamy.

In *The Observatory* for 1899 July the Astronomer Royal gave a table of the comparison of the number of stars in the Greenwich Astrographic Catalogue, zones $+64°$ to $+70°$, with those in B.D. and in the A.G.C. (Helsingfors and Christiania). The total number of stars is given for each hour of R.A. (58,170 stars for the twenty-four hours), the number per square degree—the mean being 70·0—the number in B.D. and in A.G.C., and the ratios to Greenwich measures; these ratios are 5·8 and 11·7 respectively. It should be remarked that all the plates had exposures of 6^m, 3^m, and 20^s; that all the plates not showing—with the shortest exposure—stars of the 9·0 mag. on Argelander's scale were rejected; and, thirdly, by the method adopted for measurement, which avoids overlap of adjacent plates, no stars are counted more than once: that article suggested a similar discussion of the Oxford measures.

Firstly, for reasons which need not be entered into here,* the Oxford plates have not all been taken with the uniform exposures of 6^m, 3^m, and 20^s, but these only will be used in this discussion; secondly, the plates are not so consecutive or contiguous, though as numerous, as those used in forming the table for Greenwich; and, thirdly, the basis for the rejection of a plate was not the visibility of the ninth magnitude stars, but the criterion of having three times the number of stars counted within the same area on Argelander's charts, slight allowance being sometimes made if the plate had already been measured and the total number of stars came near the limit. Table I. shows that an average of 4·0 times B.D. stars has been maintained, and 7·4 times the stars in the Cambridge Catalogue.

In spite of these differences the following table may be regarded as fairly comparable with that for Greenwich: the numbers for Greenwich are not repeated, but may be gathered from the Plate 1 accompanying this table.

* *23rd Report to the Board of Visitors, University Observatory, Oxford*, p. 7.


DISTRIBUTION OF STARS
PER SQUARE DEGREE
STARS
R.A. 0ʰ
3ʰ
6ʰ
9ʰ
12ʰ
15ʰ
18ʰ
21ʰ
0ʰ R.A.
OXFORD
GREENWICH
PARIS
POTSDAM
FROM PHOTOGRAPHS, 3 MIN EXPOSURE

[redacted]

Table I.

Hour.	No. of plates.	Total stars measured.	Average No. of stars.	No. per sq. deg.	Stars in B.D. same area.	Ratio Oxford to B.D.	Stars in Camb. same area.	Ratio Oxford to Camb.	Hour.
0	35	9283	265	56	2005	4·6	1393	6·7	0
1	28	7227	258	55	1666	4·3	859	8·4	1
2	25	5784	231	49	1207	4·8	690	8·4	2
3	21	5428	259	55	1239	4·4	599	9·0	3
4	18	3224	179	38	744	4·4	328	9·8	4
5	23	6578	286	61	1896	3·5	822	8·0	5
6	20	9322	466	99	2541	3·7	988	9·4	6
7	23	6533	284	60	2002	3·3	934	7·0	7
8	22	4751	216	46	1403	3·4	683	7·0	8
9	25	4216	169	36	1284	3·3	600	7·0	9
10	19	2733	144	31	880	3·1	499	5·5	10
11	12	1263	105	22	485	2·6	262	4·9	11
12	18	2407	134	29	760	3·2	422	5·7	12
13	23	2574	112	24	899	2·9	530	4·9	13
14	19	2718	143	30	802	3·4	449	6·0	14
15	12	1668	139	30	575	2·9	287	5·8	15
16	13	2208	170	36	728	3·0	403	5·5	16
17	12	3024	252	54	918	3·3	478	6·3	17
18	16	5764	360	77	1574	3·7	901	6·4	18
19	17	13189	776	165	2095	6·3	1239	10·6	19
20	23	12877	560	119	2725	4·7	1754	7·4	20
21	27	10673	395	84	2410	4·4	1686	6·3	21
22	29	9768	337	72	2219	4·4	1165	8·4	22
23	33	8327	252	54	2091	4·0	1097	7·6	23
Sums	513	141539	...	...	35148	...	19068	...	...
Weighted means			276	58·7	...	4·0	...	7·4	...

From an inspection of the Greenwich curve in Plate 1 a very prominent maximum stands out at 21^h and 22^h, but that at 5^h and 6^h is less pronounced; in fact, the distribution throughout the twenty-four hours is relatively more uniform, and is maintained at a higher ratio per square degree than in the Oxford zones, where two marked maxima occur at 6^h and 19^h, and a rather definite minimum at 11^h–13^h. While the Greenwich mean density is 70·0 stars per square degree, that at Oxford is 58·7 stars.

The proximity of the Greenwich zones to the Milky Way is

in fact more continuous than that of the Oxford zones, which cut the Milky Way almost at right angles, at R.A. 5^h 30^m to 7^h 15^m, and at 17^h to 21^h; whilst the Greenwich plates are actually in it from R.A. 19^h to about 5^h.

I have also collected information from the Paris Observatory Reports for 1893–97 for the Paris zones, which are contiguous to the Oxford zones on the southern side, and for the Potsdam zones * on the northern side; the results are exhibited in Table II., and included in Plate 1.

TABLE II.

Average numbers of stars measured on plates.

	Paris.				Potsdam.	
Hour.	Zone + 22°. Stars.	Zone + 23°, Stars.	Zone + 24°. Stars.	Stars per sq. deg.	Zones + 32° to + 37°. Stars.	Stars per sq. deg.
0	202_8	254_7	192_4	47	124_3	26
1	132_7	238_8	244_1	41	127_3	27
2	275_6	195_7	170_8	44	110_1	21
3	324_2	171_8	234_5	45	63_1	13
4	...	278_6	176_8	47	...	...
5	593_5	735_8	448_7	127	629_{18}	134
6	780_7	1066_7	788_8	187	216_2	46
7	427_7	629_7	451_7	107	166_4	35
8	369_6	339_6	196_6	64	177_7	38
9	200_3	211_7	162_6	41	117_1	25
10	...	137_7	179_2	32	73_2	16
11	...	129_7	116_7	26	57_3	12
12	176_7	118_5	126_8	30	...	...
13	112_5	97_7	167_7	27	82_1	18
14	114_3	121_5	130_8	26	...	...
15	221_7	113_6	161_7	36	73_1	16
16	209_7	246_7	239_7	49	...	...
17	277_4	421_6	618_6	97	...	...
18	...	717_6	582_2	146	412_2	88
19	...	766_8	844_7	171	866_3	184
20	1145_5	1161_7	929_7	228	589_3	125
21	552_6	667_7	645_7	133	193_1	41
22	488_3	367_6	401_8	86	...	...
23	121_1	278_7	333_7	62	...	...

The number of plates is given after each quantity.

* *Publicationen des Astrophysikalischen Observatoriums zu Potsdam, Photographische Himmelskarte*, Band I. xxviii.

The Paris plates yield results in close agreement with those of Oxford, except that the two maxima—in the Milky Way—are more pronounced, and in consequence the mean number of stars per square degree (80·4) is even higher than that for Greenwich (70·0). With reference to this point it may be remarked that the two maxima in the Oxford curve are reduced in magnitude by the omission of a number of plates in the Milky Way which received exposures different from 6^m, 3^m, 20^s, and by the inclusion of some old plates which in this rich region contained enough stars for the purposes of the Astrographic Catalogue, though in a poorer region similar plates have been rejected.

To examine the influence of galactic latitude on such numbers the galactic latitudes of the hourly groups, both for Oxford and Greenwich, were read from a globe. The mean declination of the Oxford zones has been taken, 28° (probably +27° would be a more correct mean of the plates actually used in this paper), and the pole of the galaxy as $12^h\ 41^m\ 20^s + 27°\ 21'$*: these readings are given in Table III. column (2). Column (3) shows the actual mean number of stars measured, as in Table I. or in the Greenwich Table; these two quantities were then taken as arguments, and a curve (Plate 2, diagrams 1 and 2) drawn through the points plotted for each hour of R.A., the ordinates (column 4) were then read from this curve and compared with column (3), and a difference (Oxford or Greenwich *minus* Oxford Curve) formed (column 5); the percentage of deviation is given in column (6).

TABLE III.

Oxford.

R.A.	Galactic Latitude.	No. of Stars.	Curve.	Obsn. *Minus* Curve.	Percentage.	R.A.	Galactic Latitude.	No. of Stars.	Curve.	Obsn. *Minus* Curve.	Percentage.
h	°					h	°				
0½	+35	265	200	+ 65	+ 24	12½	−88	134	115	+ 19	+15
1½	+34	258	205	+ 53	+ 20	13½	−80	112	115	− 3	− 3
2½	+29	231	230	+ 1	0	14½	−66	143	125	+ 18	+12
3½	+21	259	290	− 31	− 12	15½	−53	139	140	− 1	0
4½	+13	179	410	−231	−129	16½	−40	170	170	0	0
[illegible]	+ 1	286	740	−454	−159	17½	−27	252	250	+ 2	+ 1
[illegible]	−10	466	470	− 4	− 1	18½	−14	360	385	− 25	− 7
[illegible]	−22	284	285	− 1	0	19½	− 2	776	725	+ 51	+ 7
[illegible]	−35	216	200	+ 16	+ 7	20½	+ 8	560	505	+ 55	+10
[illegible]	−48	169	150	+ 19	+ 11	21½	+18	395	320	+ 75	+19
[illegible]	−61	144	130	+ 14	+ 10	22½	+25	337	265	+ 72	+21
[illegible]	−74	105	120	− 15	− 14	23½	+33	252	200	+ 52	+20
[illegible]	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)

* *Uranometria Argentina*, Gould, p. 370.

Diagram 1.

OXFORD

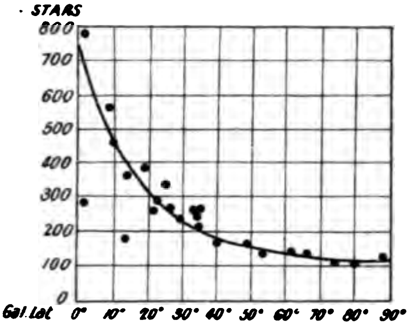


Diagram 2.

GREENWICH.

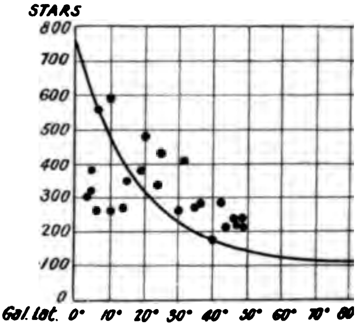
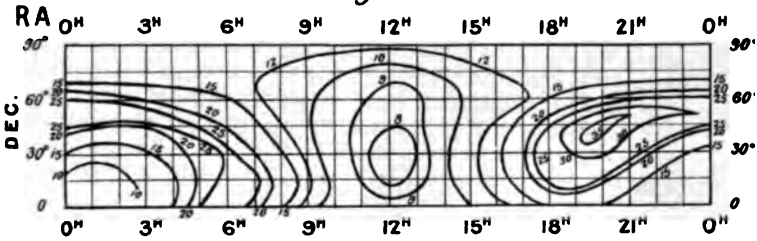


Diagram 3.



EQUAL DENSITY LINES FOR B.D. STARS

Diagram 4.

GALACTIC LONGITUDE

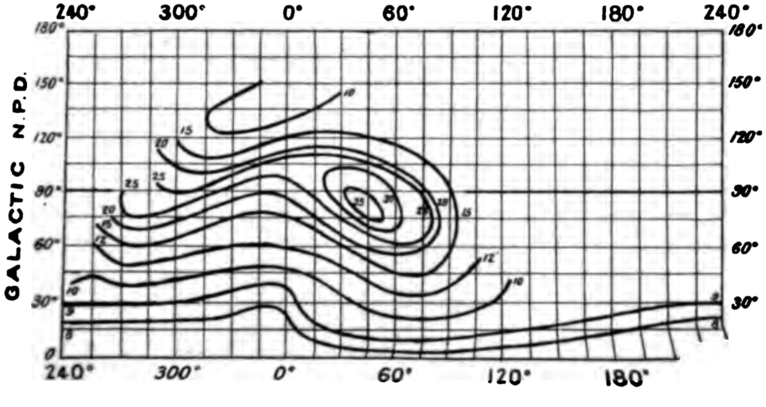


TABLE III—*continued.*

Greenwich.

R.A.	Galactic Latitude.	No. of Stars.	Curve.	Obsn. *Minus* Curve.	Per-centage.	R.A.	Galactic Latitude.	No. of Stars.	Curve.	Obsn. *Minus* Curve.	Pe[r-] cent[age].
h	°					h	°				
0½	+ 4	305	630	−325	−108	12½	+49	218	150	+ 68	+
1½	+ 5	310	600	−290	− 94	13½	+48	231	150	+ 81	+
2½	+ 6	261	585	−324	−124	14½	+46	236	155	+ 81	-
3½	+10	260	480	−220	− 85	15½	+42	289	175	+114	+
4½	+14	262	390	−128	− 41	16½	+37	283	195	+ 88	+
5½	+18	377	315	+ 62	+ 16	17½	+31	414	225	+189	+
6½	+24	343	275	+ 68	+ 20	18½	+25	433	270	+163	+
7½	+30	264	230	+ 34	+ 13	19½	+20	486	315	+171	-
8½	+35	271	200	+ 71	+ 26	20½	+15	356	385	− 29	-
9½	+40	184	184	0	0	21½	+10	594	475	+119	-
10½	+44	217	160	+ 57	+ 26	22½	+ 7	564	564	0	
11½	+48	247	150	+ 97	+ 29	23½	+ 5	378	600	−222	-
(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	

For Oxford the agreement is good; but there are two exceptional hours, $4\frac{1}{2}^h$ and $5\frac{1}{2}^h$, which cannot be brought within reasonable agreement without throwing out a considerable portion of the curve. But it is at once obvious that neither this Oxford curve, which has been used for Greenwich differences in Table III., nor any other curve, will suit the results from the Greenwich plates; in other words the number of stars on a plate does not vary simply as any function of the galactic latitude. This indeed appears from the B.D. To bring out the facts clearly the following information was obtained.

The number of stars per square degree was formed from the stars in B.D. for every tenth degree and for each hour.

The points were plotted and curves drawn; these curves were used as a basis for forming diagram 3 (Plate 2).

To show more clearly the relation of the curves of equal density to the galaxy, I have made diagram 4 (Plate 2) where the abscissæ represent galactic longitudes and the ordinates galactic N.P.D.

It can be seen that the Oxford zones pass through the minimum area of star distribution (according to the stars given in the B.D.), and are within a region containing an average of less than 12 stars per square degree from R.A. $8\frac{1}{2}^h$ to 16^h, also again from 0^h to 3^h; in fact more than half the Oxford zones. On the contrary, they almost cut the Milky Way at right angles at $5^h\ 30^m$, and leave it at $6\frac{3}{4}^h$ or 7^h, and again enter at $17\frac{1}{2}^h$ and remain within it till nearly 22^h. The reason of the less variation between the Greenwich maxima and minimum is also apparent, but the fall at 20^h is unexplained. It must be

Diagram 1.

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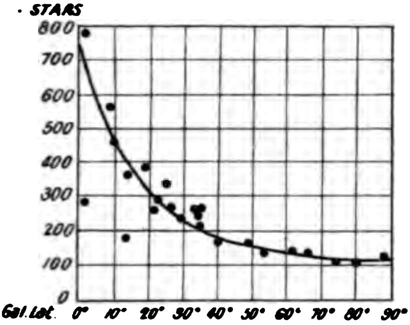


Diagram 2.

GREENWICH.

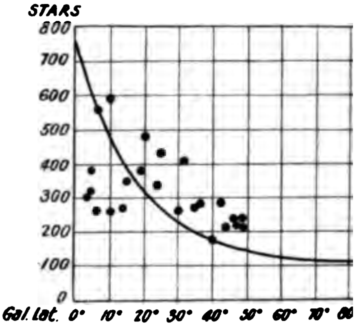
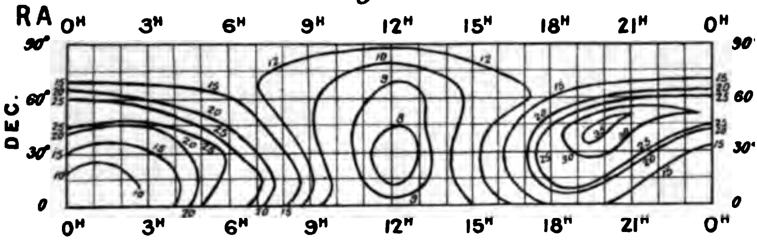


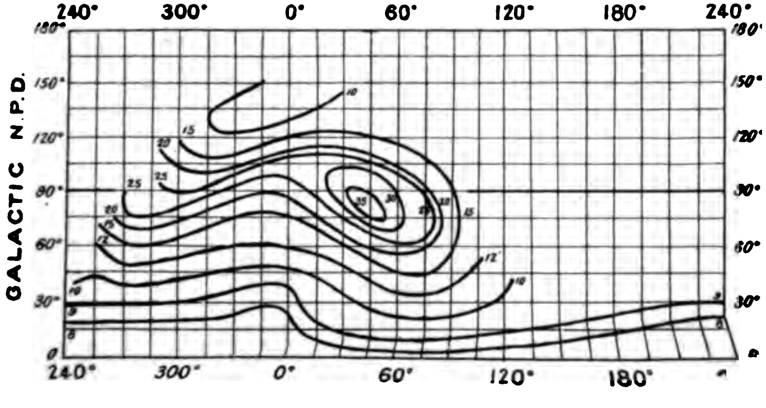
Diagram 3.



EQUAL DENSITY LINES FOR B.D. STARS

Diagram 4.

GALACTIC LONGITUDE



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remembered that in comparing Plate 1 and Plate 2, diagram 3, the comparison is one between density from B.D. stars (to the $9\frac{1}{2}$ mag.) and from photographs giving stars as low as the $10\frac{1}{2}$ and 11 magnitudes.

When all the zones are completed it will be interesting to form a similar set of curves of equal density for stars to the 11th magnitude shown on the photographs and compare them with these found from Argelander's eye observations.

Comparison of the Diameters of the Images of Stars on the Greenwich Astrographic Plates with the Magnitudes given in the 'Bonn Durchmusterung.' By F. W. Dyson, M.A., and H. P. Hollis, B.A.

§ 1. This paper consists of a comparison of the diameters of the images on 232 astrographic plates with the magnitudes of the stars as given in the *Bonn Durchmusterung*. The number of stars contained in the *B. D.* varies from about 20 to 100 per plate, so that the diameters of more than 10,000 images have been considered. The object of the paper is not to obtain a formula connecting diameter and magnitude from any physical considerations, but rather to tabulate observations, to see what changes there are from plate to plate, and to test the uniformity of Argelander's scale.

The photographs considered are those whose centres are at dec. +65°, +66°, and +67°. They were taken at various times between 1892 April and 1898 March. The images whose diameters have been measured twice in the regular measurement of the Greenwich plates had an exposure of 6^m. The plates used were "Ilford Special Rapid," "Mawson," and "Rocket."

The diameters of the images are measured in units of $0''\cdot3$ or $\frac{1}{1000}$th of one réseau interval by each of the measurers, and the sum of the measures is given, so that the measures of diameter are expressed in units of $0''\cdot15$. Measurement of the diameters of the photographic images of stars are necessarily somewhat arbitrary, especially at some distance from the centre of the field, when the images are elongated and faint. The measurers were instructed to make some allowance for this, the general principle being to give the diameter the stars would have had if near the centre of the plate.

§ 2. The diameters of all the stars contained in the *B. D.* were tabulated for each plate. Plate 1548, the first plate in zone 67°, may be given as a specimen.

9·5		9·4	9·3	9·2	9·1	9·0	8·9	8·8	8·7	8·6	8·5	8·4
26	22	32	20	32	36	32	44	37	...	34	42	46
24	26	36	32	36	(63)*	46	...	43	...	28	44	52
23	20	38	24	32	36	38	...	...	...	...	42	45
25	28	23	35	39	36	50	44_1	40_2	...	31_2	43_3	48_2
23	30	23	36	...	...	49						
23	32	...	...	...	...	24	8·3	8·1	8·0	7·8	7·2	7·0
28	20	...	...	...	...	51	58	57	43	51	76	76
26	12	...	...	...	...	...	...	45	...	...	...	...
24	26	...	...	...	...	...	...	...	...	...	...	...
35	22	...	...	...	...	...						
...	25_{20}	30_8	29_8	35_4	36_2	41_7	58_1	51_2	43_1	51_1	76_1	76_1

* In extreme corner of plate.

This shows the nature and extent of the material to be dealt with. The accidental differences are occasionally large. From examination of a number of discordant cases, we conclude that the differences are not usually due to errors of measurement.

§ 3. It was first necessary to determine whether there were systematic differences depending on the distance from the centre of the plate. The images on 100 plates were divided into two classes, those inside the central square bounded by the réseau lines $x=6$ to $x=22$, and $y=6$ to $y=22$, and those outside this square; these limits being chosen as dividing the measured portions of the plates into approximately equal areas. The mean diameters in the two divisions of each plate of stars whose *B. D.* magnitudes were 9·5, 9·4, &c. to 8·4 were obtained, and the differences formed. It was found that the diameters in the inner square were slightly less than those in the remainder of the plate, but the systematic difference was not large. The mean distance of stars in the inner square from the centre is 30′, and in the remainder is about 57′. The following were the differences obtained, the subscript figures denoting the number of plates from which the result was derived :—

Excess of Diameters of Images at Mean Distance of 57′ *from the Centre over those at Mean Distance* 30′.

Mag. *B. D.*	9·5	9·4	9·3	9·2	9·1	9·0	8·9–8·7	8·6–8·4
Excess of Diam.	$+0·7_{107}$	$+1·6_{96}$	$+1·2_{16}$	$+1·5_{53}$	$+3·5_{35}$	$+2·7_{80}$	$+2·4_{87}$	$3·1_{32}$

As it will be shown that a difference in the diameter of 1·5 corresponds in the mean to a difference of $0^{m}·1$, it follows that there is a difference of about $0^{m}·05$ for stars of *B. D.* $9^{m}·5$; of about $0^{m}·1$ for stars of *B. D.* 9^{m} to ·$49^{m}·2$, and of about $0^{m}·2$ for

stars of *B. D.* $9^m{\cdot}1$ to $8^m{\cdot}5$. For stars brighter than $8^m{\cdot}4$ there is practically no material available.

No attempt has been made to trace these differences any further, though they may vary with the measurers, the kind of plates used, and the quality of the nights when the photographs were taken.

The differences are much smaller than the accidental differences of measurement of the images or the estimates of diameter in the *B. D.* All images have consequently been included which come within the limits of measurement of the plates—that is, in 2° square.

§ 4. All the photographs in the three zones were treated in the same way as the specimen plate given in § 2.

As it was found that the mean value of the $9^m{\cdot}5$ images varied from 12 on one plate to 43 on another, and, similarly, the mean value of the $9^m{\cdot}0$ diameters varied between even wider limits, the plates were first arranged in order of the magnitude of the mean diameters of the images of the $9^m{\cdot}5$ stars upon them. The range of magnitude considered was only as high as $8^m{\cdot}0$, in consequence of the paucity of brighter stars. These means are given in Table I. The letters A, B, C in the first column are used to distinguish the zones 65°, 66°, 67°, and the number with them is the number of the plate in the zone. This number may be used to give the right ascension of the centres of the plates, viz.:—

In Zone 65° R.A. of Centre = (Zone No.) × $18^m - 9^m$
„ 66 „ „ = (Zone No.) × $18 - 18$
„ 67 „ „ = (Zone No.) × $20 - 10$

The numbers in the second column are the numbers of the plates, which are according to the order in which they were taken. The date is given in the third column. The letters in the fourth column indicate the kind of plate used. The mean diameters corresponding to the *B. D.* magnitudes $9^m{\cdot}5$ to $8^m{\cdot}0$ are then given. Meteorological notes from the observers' note-books are given in the last column.

TABLE I.

No. in Zone.	No.	Date.		Mean Diameters of Images of stars							
				9·5.	9·4.	9·3	9·2.	9·1.	9·0.	8·9.	8·8.
B 37	322	1892. Apr.	2	33_{9}	40_{1}	37_{4}	...	42_{2}	36_{5}	...	44_{1}
B 35	325		8	26_{13}	31_{9}	32_{4}	...	35_{1}	42_{1}	32_{2}	...
A 39	331*		9	21_{5}	28_{5}	27_{7}	36_{1}	...	45_{4}	40_{1}	36_{6}
A 41	336		11	30_{2}	29_{3}	25_{2}	25_{2}	26_{1}	32_{3}	...	37_{1}
A 43	345		25	21_{9}	22_{3}	25_{3}	...	22_{2}	30_{4}	38_{8}	35_{2}
A 46	346		25	17_{5}	20_{2}	20_{2}	...	31_{4}	26_{2}	36_{1}	34_{4}
A 51	359		29	22_{9}	24_{5}	25_{3}	29_{2}	34_{2}	35_{2}	36_{2}	39_{1}
A 56	392	May	23	33_{12}	37_{6}	41_{4}	...	48_{1}	43_{6}	...	50_{1}
C 47	397		28	39_{10}	37_{5}	...	39_{1}	43_{2}	49_{6}	56_{3}	54_{2}
C 49	419	June	10	29_{9}	26_{3}	34_{4}	32_{1}	38_{1}	44_{3}	...	44_{1}
A 55	423		13	32_{6}	28_{2}	31_{5}	31_{4}	33_{1}	37_{7}	40_{2}	44_{1}
A 66	426		13	22_{22}	31_{9}	28_{11}	34_{1}	35_{4}	36_{5}	34_{5}	39_{4}
B 57	427		15	12_{15}	9_{4}	13_{3}	15_{3}	12_{3}	27_{3}	...	...
A 57	437		20	32_{15}	26_{5}	36_{3}	39_{3}	40_{5}	55_{2}	44_{1}	47_{3}
B 61	441		23	23_{17}	31_{3}	28_{6}	35_{5}	35_{2}	34_{6}	36_{2}	39_{2}
B 64	443		23	32_{21}	37_{6}	36_{5}	48_{2}	44_{3}	41_{4}	38_{1}	42_{1}
B 65	444		23	29_{28}	31_{5}	34_{4}	36_{2}	41_{2}	39_{5}	43_{4}	39_{3}
B 59	446		24	28_{17}	40_{6}	39_{8}	39_{8}	...	44_{2}	...	50_{1}
B 71	522	Aug.	29	31_{28}	35_{12}	30_{9}	39_{7}	38_{7}	41_{1}	40_{1}	42_{2}
A 65	534	Sept.	3	28_{13}	28_{3}	37_{4}	36_{1}	24_{1}	33_{7}	37_{5}	40_{3}
A 70	535		3	27_{22}	30_{9}	...	34_{5}	37_{3}	44_{2}	28_{2}	36_{3}
A 71	536		3	31_{29}	36_{5}	34_{7}	32_{4}	36_{10}	43_{2}	46_{2}	38_{4}
C 71	556		14	29_{28}	33_{3}	29_{7}	35_{5}	38_{5}	36_{4}	32_{1}	...
B 78	559		15	26_{23}	34_{5}	36_{9}	38_{5}	38_{1}	43_{8}	33_{3}	48_{3}
C 5	587	Oct.	3	25_{22}	34_{6}	28_{7}	35_{3}	27_{1}	38_{4}	39_{2}	40_{2}
B 7	658	Nov.	30	23_{17}	29_{7}	35_{1}	32_{3}	43_{1}	36_{1}	35_{2}	41_{4}
C 68	660	Dec.	2	12_{12}	7_{3}	14_{7}	14_{2}	20_{2}	21_{1}	20_{3}	20_{2}
C 8	703		24	16_{9}	25_{9}	24_{3}	29_{4}	36_{4}	39_{2}	38_{2}	45_{3}
B 11	724	1893. Jan.	4	19_{7}	22_{3}	28_{5}	22_{4}	...	27_{2}	21_{1}	...
B 26	726		4	22_{4}	31_{3}	29_{2}	24_{5}	38_{2}	32_{3}	30_{1}	...
A 11	748	Feb.	5	28_{10}	35_{4}	38_{4}	...	44_{2}	40_{5}	...	...
B 25	763		8	29_{11}	32_{9}	...	38_{2}	41_{3}	38_{1}	35_{1}	...
B 23	776		10	34_{9}	40_{4}	29_{1}	37_{5}	41_{2}	40_{4}	...	41_{2}
B 21	786		14	37_{8}	38_{5}	40_{2}	44_{1}	44_{2}	42_{3}	...	...
C 23	792		16	31_{9}	33_{1}	27_{1}	32_{3}	...	41_{6}	41_{1}	43_{2}

TABLE I.

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1.	8·0.	Plate.	Notes.
51_2	...	...	...	51_2	54_1	...	49_2	Ilford	
66_1	...	...	...	46_1	...	40_1	50_2	,,	Moonlight.
...	44_1	...	67_1	39_1	...	...	...	,,	
42_2	42_1	...	...	44_2	43_2	...	...	,,	Hazy. Moonlight.
...	...	35_2	...	36_2	44_1	...	58_1	,,	
26_1	...	38_2	...	44_2	...	...	52_1	,,	
36_1	...	...	...	50_1	...	41_1	37_2	,,	
...	62_1	44_1	...	...	...	...	52_1	,,	
55_2	61_1	...	...	...	...	...	...	,,	Hazy. Clouds.
44_2	36_1	56_1	...	...	...	...	58_2	Mawson	
...	32_1	44_1	...	52_1	47_2	...	45_1	,,	
40_2	...	45_4	...	48_1	45_2	...	54_2	,,	
23_1	...	...	...	...	...	...	33_2	,,	Clouds passing.
57_1	...	58_1	...	...	...	...	56_2	,,	
40_1	...	43_2	...	...	...	...	56_1	Ilford	White sky.
40_1	47_2	55_2	48_2	...	...	...	...	,,	,,
51_2	47_1	45_2	...	...	62_2	51_2	58_2	,,	,,
48_1	...	52_2	50_1	53_2	...	...	...	,,	
49_4	47_1	54_1	...	56_1	...	...	...	,,	Clouds.
56	...	38_5	...	...	...	...	65_1	,,	
39_2	39_2	38_2	39_1	...	...	...	...	,,	
44_2	50_1	28_1	43_1	50_2	42_6	...	40_1	,,	Interrupted by clouds.
42_2	...	46_2	...	46_4	...	44_1	63_2	,,	
47_1	50_2	43_5	...	53_1	...	...	44_1	Mawson	Interrupted by clouds.
47_1	...	52_2	...	...	68_1	48_2	48_2	,,	Windy.
39_1	45_2	43_2	40_1	...	...	...	42_1	Ilford	Interrupted by clouds.
29_2	26_2	25_6	24_1	30_1	...	49_1	20_1	,,	Moonlight. Hazy.
...	39_1	...	40_1	...	...	51_1	...	,,	
...	40_2	41_2	...	33_1	...	...	44_5	,,	
38_1	29_1	41_2	36_1	...	41_2	41_1	45_1	,,	
47_2	50_1	48_5	46_1	44	...	...	68	Mawson	
...	...	43_1	...	...	...	...	46_1	Ilford	
44_2	...	41_2	50_1	...	...	70_1	60_1	,,	
...	...	63_2	66_1	...	73_2	66_1	80_1	,,	
...	38_1	49_2	...	61_1	48_1	54_1	55_4	,,	

No. in Zone.	No.	Date.		Mean Diameters of images of stars 9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9.	8·8.
		1893.									
B 20	797	Feb.	25	33_7	37_2	38_3	43_3	50_3	48_1	54_2	...
A 21	807	Mar.	1	32_{10}	33_1	40_4	45_2	...	43_5	...	50_1
C 28	811		4	26_3	25_2	36_6	36_2	38_4	37_5	...	44_3
B 24	813		8	23_6	24_3	35_3	66_1	33_1	35_2	...	29_1
A 26	849		17	28_{14}	31_1	...	40_5	30_2	40_1	...	...
A 27	850		17	18_{13}	20_1	25_2	27_4	29_3	36_1	28_1	30_4
A 30	852		17	28_{11}	31_7	30_4	37_2	41_4	44_3	41_2	...
A 31	853		17	25_{12}	29_3	30_1	38_1	37_3	33_2	...	...
A 32	854		17	26_9	23_9	36_2	32_3	34_2	37_2	42_1	36_2
A 33	855		17	26_{10}	29_7	33_4	39_3	38_2	35_2	40_1	44_1
A 34	856		17	30_8	38_7	31_5	24_1	...	39_3	43_3	44_1
C 33	859		17	30_8	35_1	33_4	...	44_1	35_5	...	...
C 37	862		17	28_{11}	32_3	...	...	33_1	40_3	...	...
C 41	865		17	28_7	32_2	...	41_3	31_1	38_2	...	67_1
B 30	872		18	29_{17}	34_3	35_4	41_2	37_2	38_5	...	...
C 25	877		19	27_9	26_2	26_1	24_1	31_3	41_2	...	40_2
B 32	899		23	28_{11}	26_7	38_7	38_1	33_1	39_3	...	...
B 39	938		29	20_4	24_5	24_3	26_4	30_1	33_3	...	33_1
B 41	940		29	17_{11}	21_3	27_5	28_1	...	26_1	32_1	...
B 42	941		29	23_{13}	20_2	24_1	23_1	38_1	30_3	...	32_1
B 43	942		29	26_3	30_1	...	31_3	38_1	34_6	31_1	45_3
B 34	951	Apr.	2	24_6	34_5	34_5	...	35_3	...	39_2	49_2
B 46	962		3	25_7	36_3	...	40_2	40_1	42_2	43_2	35_1
B 66	1236	June	24	32_{22}	38_6	40_9	46_1	36_6	45_2	47_3	42.
A 64	1274	July	7	24_{20}	30_3	26_2	30_3	30_4	36_8	47_2	43_1
A 63	1321	Aug.	2	18_{22}	19_6	18_4	17_1	14_1	25_3	25_4	32_1
A 72	1334		5	30_{16}	39_3	36_8	39_4	33_5	38_8	34_2	38_9
C 61	1416	Sept.	2	31_{12}	37_3	42_7	...	50_2	42_2	...	54_3
C 1	1548	Oct.	22	25_{20}	31_5	29_5	35_4	36_3	42_7	44_1	40_2
C 2	1549		22	29_{19}	33_7	44_4	43_2	43_2	42_3	44_2	...
B 72	1587	Nov.	9	28_{19}	33_6	30_8	32_6	33_3	38_8	...	37_7
B 73	1588		9	27_{27}	29_{11}	35_{11}	34_2	34_4	40_6	45_1	40_5
A 74	1593		12	23_{20}	25_6	25_5	29_4	36_4	41_3	37_3	54_1
C 6	1598		12	30_{13}	35_{11}	39_4	40_4	45_3	49_2	24_1	49_3
A 9	1610		17	29_{21}	34_7	41_3	42_5	42_1	53_1	41_2	...
A 77	1613		22	20_{22}	26_{13}	$2?_9$	30_7	40_2	$3?_8$	32_4	41_2

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1	8·0.	Plate.	Notes.
44_2	...	...	...	...	...	...	...	Ilford	
...	54_1	44_1	44_1	...	54_1	...	...	„	Interrupted by clouds.
36_1	...	43_1	47_1	45_2	...	...	51_2	„	Thick sky.
29_1	...	...	44_1	38_2	...	...	58_1	„	
40_1	...	40_1	...	...	48_2	...	45_2	„	Wind high. Clouds appear and disappear suddenly.
22_1	...	30_1	...	...	...	...	...	„	
46_1	...	46_2	...	...	...	...	...	„	
40_2	...	45_2	...	46_1	...	...	...	„	
...	34_1	40_2	...	44_1	...	44_1	...	„	
...	...	...	53_1	...	...	...	...	„	
...	...	...	...	51_2	...	40_1	47_2	„	
44_1	41_1	...	...	51_1	43_1	...	45_2	Mawson	
...	...	53_2	47_1	38_2	...	40_1	...	„	
46_1	55_2	...	66_1	...	...	...	...	„	
43_2	56_1	...	46_2	...	...	...	...	Ilford	
...	43_1	...	40_4	...	36_1	45_1	53_1	„	Sky misty. Images steady.
46_1	46_1	48_1	...	49_2	...	...	49_1	„	
26_1	36_1	...	36_1	37_1	...	...	42_1	Mawson	Bright Moon. Clouds.
...	40_1	...	34_1	35_1	...	...	...	„	
40_1	40_1	48_1	...	46_1	46_1	29_1	...	„	
...	42_1	44_1	...	52_2	...	...	72_1	„	
...	...	...	39_1	43_2	54_1	...	47_1	Ilford	
44_1	62_2	...	...	85_1	...	...	60_1	„	
51_3	...	49_3	62_1	59_1	51_1	...	60_1	Mawson	
55_2	...	32_1	43_2	45_1	42_1	51_1	59_1	Ilford	
26_1	34_1	38_2	34_2	...	35_1	...	...	„	
42_1	48_2	45_3	48_3	43_1	...	44_2	55_2	„	
43_3	...	54_2	...	...	55_1	...	...	Mawson	
...	31_2	43_3	48_3	58_1	...	51_2	43_1	„	Heavy dew. Definition bad.
51_2	47_1	49_3	...	...	69_2	...	45_2	„	Definition improving.
36_2	...	29_2	...	48_2	...	...	50_3	„	Windy. Cloudy after.
39_1	43_2	45_4	50_5	42_1	58_1	51_2	76_1	„	
44_1	45_2	44_2	46_1	...	40_1	53_3	...	„	
46_1	53_2	61_2	60_2	76_1	...	...	61_2	„	
45_2	...	45_2	50_1	47_1	46_1	...	63_1	„	
...	44_3	43_1	...		...	...	...	„	Moonlight.

No. in Zone.	No.	Date.		Mean Diameters of images of stars							
				9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9	8·8.
A 3	1631	1893. Dec.	1	20_{20}	27_{5}	29_{5}	37_{5}	39_{5}	38_{7}	44_{1}	42_{2}
A 4	1632		1	26_{20}	28_{10}	37_{2}	38_{6}	40_{3}	44_{6}	42_{2}	49_{4}
A 6	1633		1	23_{24}	34_{9}	35_{3}	39_{3}	...	36_{5}	45_{4}	45_{5}
C 7	1634		1	19_{16}	31_{7}	35_{4}	28_{2}	40_{3}	45_{6}	44_{2}	42_{2}
A 10	1640		1	25_{13}	30_{5}	41_{3}	35_{6}	38_{6}	52_{2}	52_{1}	...
C 9	1641		1	25_{8}	...	29_{1}	46_{1}	38_{2}	38_{7}	...	...
C 13	1645		1	33_{9}	30_{2}	33_{5}	39_{6}	50_{3}	46_{7}	...	36_{7}
C 14	1646		1	29_{8}	33_{4}	56_{2}	41_{2}	33_{5}	42_{3}	48_{1}	53_{2}
C 15	1647		1	28_{15}	36_{5}	26_{2}	...	30_{1}	43_{3}	...	34_{7}
C 16	1648		1	...	23_{7}	27_{6}	24_{2}	35_{5}	32_{3}	...	31_{2}
C 18	1649		1	29_{5}	38_{7}	42_{3}	37_{3}	42_{3}	38_{2}	...	...
A 18	1650		1	29_{14}	26_{3}	29_{7}	37_{4}	49_{2}	44_{9}	...	54_{2}
A 22	1653		1	43_{2}	...	44_{1}	45_{5}	46_{2}	39_{5}	...	52_{6}
A 23	1654		1	32_{9}	44_{3}	45_{3}	48_{1}	46_{1}	63_{2}	...	50_{1}
A 80	1656		2	21_{31}	20_{9}	25_{14}	36_{2}	35_{4}	25_{5}	43_{2}	40_{1}
B 3	1681		9	23_{23}	34_{5}	38_{5}	39_{6}	41_{1}	43_{7}	42_{2}	58_{2}
B 9	1691		14	19_{14}	25_{7}	29_{3}	33_{2}	35_{4}	41_{3}	34_{1}	43_{2}
C 19	1708		22	29_{8}	29_{5}	38_{3}	38_{1}	41_{2}	49_{3}	...	...
C 22	1710		22	29_{7}	34_{6}	22_{2}	...	51_{1}	45_{4}	...	42_{1}
C 20	1747	1894. Jan.	12	32_{14}	39_{4}	39_{3}	39_{3}	43_{5}	41_{6}	...	33_{1}
C 17	1759		25	40_{7}	36_{4}	34_{2}	36_{3}	...	38_{4}	56_{1}	45_{3}
B 18	1762		30	38_{6}	41_{5}	38_{7}	35_{2}	58_{2}	43_{3}	...	43_{3}
A 24	1774	Feb.	4	36_{9}	40_{5}	37_{4}	52_{2}	48_{4}	40_{3}	...	...
C 29	1863	Mar.	11	34_{5}	33_{8}	41_{4}	40_{2}	37_{2}	43_{2}	...	46_{3}
C 27	1885		21	29_{14}	31_{9}	42_{1}	42_{1}	...	32_{1}	47_{1}	43_{2}
C 26	1899		26	32_{15}	45_{4}	38_{5}	42_{1}	42_{1}	48_{1}	40_{3}	48_{1}
C 34	1921	Apr.	1	32_{5}	37_{4}	40_{2}	43_{3}	43_{2}	40_{4}	43_{1}	42_{1}
C 30	1932		3	30_{5}	31_{2}	43_{4}	...	36_{3}	38_{1}	41_{1}	51_{2}
A 44	1995		21	31_{6}	33_{6}	40_{2}	...	...	48_{3}	38_{1}	...
A 42	2022	May	7	26_{9}	27_{4}	27_{3}	40_{5}	33_{3}	40_{5}	29_{2}	43_{1}
C 42	2033		12	22_{5}	29_{3}	32_{2}	32_{2}	35_{2}	47_{4}	37_{3}	29_{1}
C 43	2034		12	21_{6}	28_{8}	33_{1}	32_{2}	31_{2}	44_{3}	...	...
A 52	2044		17	21_{14}	25_{2}	40_{2}	...	30_{2}	39_{6}	...	42_{2}
A 54	2046		17	21_{11}	29_{3}	35_{1}	33_{3}	42_{1}	...	44_{2}	40_{2}
A 58	2048		17	30_{12}	30_{4}	29_{6}	33_{4}	42_{1}	40_{2}	...	44_{2}
C 51	2056		21	35_{12}	39_{5}	41_{3}	45_{2}	32_{1}	52_{2}	45_{1}	54_{2}
A 49	2074		31	28_{11}	26_{3}	36_{5}	34_{1}	42_{1}	40_{3}	...	45_{2}
C 56	2148	July	19	31_{6}	...	37_{2}	36_{2}	38_{2}	39_{1}	46_{1}	...

[redacted]

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2	8·1.	8·0.	Plate.	Notes.
45_2	...	...	59_2	48_1	...	50_1	55_2	Mawson	
54_1	68_1	62_1	67_2	...	48_2	...	66_1	„	
50_2	61_1	56_2	46_1	48_1	47_1	...	...	„	
30_1	56_1	42_1	67_1	...	46_1	46_1	54_1	„	
62_1	52_1	60_2	...	46_1	...	...	58_1	„	
39_1	...	53_2	...	...	...	...	...	„	
40_2	52_2	52_2	62_2	...	...	62_2	71_1	„	High wind early in the evening.
55_2	43_1	61_2	...	88_1	...	...	70_2	„	Cloudy at times.
...	...	...	...	68_2	57_1	...	52_2	„	
...	...	35_2	28_2	45_2	...	...	54_2	„	
53_2	...	...	68_1	63_2	54_2	78_1	...	„	
...	38_1	...	...	...	80_1	...	83_1	„	
53_2	46_1	...	...	44_2	48_1	...	59_2	„	
44_1	...	46_1	54_1	65_2	...	58_1	...	„	
37_2	41_1	54_1	...	...	43_6	...	47_2	„	
50_2	...	58_1	...	...	...	...	...	„	
...	42_1	43_4	39_1	...	...	60_1	...	„	Sky hazy.
...	...	50_4	...	...	...	52_1	84_1	„	
40_1	46_4	...	40_1	...	...	...	...	„	
49_1	...	...	49_2	...	63_1	...	...	„	
...	...	72_2	...	...	...	...	77_1	„	
...	...	64_1	...	71_1	...	...	64_2	„	
39_1	...	...	...	58_1	48_1	...	62_1	„	
...	...	48_1	...	50_1	57_2	...	62_1	„	Slightly cloudy.
...	...	...	...	...	...	...	...	„	Clouds after.
...	...	53_1	67_1	57_2	...	...	...	„	
50_2	57_2	51_2	...	...	...	...	67_2	„	
...	37_1	46_2	55_5	50_1	...	54_1	69_2	„	
47_1	...	54_2	...	...	...	...	...	„	Clouds after.
...	41_2	...	...	51_2	...	...	...	„	
...	44_4	51_1	43_2	...	...	47_1	51_4	„	Sky misty.
41_1	...	37_2	...	...	...	...	54_2	„	Clearer.
34_2	...	47_2	...	...	...	...	72_1	„	Sky good but un-
56_1	...	43_2	54_1	57_1	...	...	...	„	settled.
53_1	...	48_2	...	...	...	...	...	„	
47_2	...	53_2	...	...	...	...	76_1	„	
...	42_1	40_2	...	...	...	40_1	...	„	
40_2	50_1	...	...	...	49_1	...	...	„	Not very clear.

No. in Zone.	No.	Date.		Mean Diameters of images of stars							
				9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9.	8·8.
C 58	2251	1894. Sept.	28	18_{27}	19_{9}	26_{4}	41_{1}	38_{2}	29_{4}	37_{1}	32_{3}
A 67	2270	Oct.	12	23_{15}	19_{2}	23_{6}	29_{2}	30_{4}	36_{7}	30_{1}	26_{1}
B 69	2279		14	24_{22}	31_{8}	30_{7}	34_{5}	33_{9}	43_{2}	44_{2}	46_{1}
A 69	2280		14	22_{18}	29_{3}	31_{7}	39_{3}	39_{2}	38_{5}	41_{3}	45_{4}
B 75	2283		14	25_{32}	31_{6}	32_{8}	35_{6}	44_{2}	37_{1}	...	45_{3}
A 2	2287		15	24_{25}	36_{12}	37_{5}	42_{3}	36_{3}	41_{6}	39_{2}	...
C 58	2288		16	20_{36}	25_{5}	27_{4}	31_{2}	26_{2}	28_{2}	44_{2}	37_{5}
C 59	2289		16	21_{33}	24_{5}	30_{6}	45_{1}	30_{6}	32_{3}	35_{2}	...
B 67	2290		16	25_{32}	24_{5}	29_{2}	...	31_{4}	35_{7}	...	36_{4}
B 79	2303		24	19_{27}	20_{5}	25_{4}	26_{4}	32_{4}	36_{1}	33_{3}	38_{1}
B 70	2308		25	21_{24}	25_{5}	27_{3}	33_{3}	39_{3}	36_{4}	38_{3}	43_{3}
C 62	2310		28	22_{19}	25_{4}	25_{2}	22_{4}	31_{7}	38_{2}	41_{3}	40_{4}
C 63	2311		28	17_{20}	17_{5}	23_{7}	23_{3}	...	34_{3}	34_{3}	30_{3}
C 64	2312		28	22_{17}	22_{5}	25_{9}	27_{2}	31_{5}	34_{6}	33_{1}	39_{4}
C 65	2313		28	18_{24}	19_{13}	23_{10}	23_{5}	32_{1}	34_{6}	29_{3}	41_{4}
C 66	2316		28	29_{24}	28_{6}	33_{4}	35_{7}	25_{1}	34_{12}	35_{1}	48_{1}
A 8	2323	Nov.	5	24_{17}	27_{3}	35_{6}	36_{2}	38_{4}	38_{4}	40_{1}	34_{1}
C 67	2331		6	32_{34}	38_{7}	36_{9}	42_{8}	46_{2}	42_{4}	54_{1}	55_{4}
C 72	2333		6	26_{33}	30_{5}	31_{2}	43_{3}	42_{4}	43_{6}	47_{2}	49_{4}
A 5	2334		6	29_{26}	36_{15}	43_{7}	39_{8}	45_{6}	43_{7}	...	39_{3}
B 68	2338		8	25_{13}	26_{8}	33_{6}	36_{1}	40_{3}	40_{3}	...	45_{2}
A 13	2367		19	32_{13}	33_{3}	37_{5}	38_{5}	45_{1}	46_{4}	57_{1}	...
A 15	2369		19	22_{16}	31_{3}	33_{9}	40_{12}	34_{3}	42_{4}	50_{2}	38_{1}
B 14	2370		19	33_{8}	33_{5}	34_{7}	44_{1}	...	46_{3}	...	44_{1}
A 1	2376		21	15_{24}	17_{13}	24_{3}	23_{5}	23_{5}	22_{3}	34_{8}	31_{2}
A 7	2380		21	31_{36}	41_{4}	47_{3}	40_{9}	43_{3}	41_{3}	49_{2}	52_{3}
B 8	2382		21	24_{18}	34_{6}	38_{4}	34_{4}	41_{3}	41_{7}	39_{1}	39_{1}
C 68	2397		25	27_{22}	30_{12}	...	38_{4}	37_{2}	41_{10}	45_{3}	42_{3}
B 10	2404		30	27_{12}	32_{7}	44_{2}	41_{2}	39_{2}	42_{1}	46_{2}	41_{1}
C 4	2406	Dec.	8	16_{14}	18_{4}	28_{4}	24_{4}	...	40_{1}	28_{8}	32_{1}
B 12	2418		19	30_{5}	33_{5}	36_{5}	30_{3}	40_{2}	43_{4}	76_{1}	47_{2}
B 13	2419		19	31_{11}	39_{3}	43_{1}	36_{6}	38_{2}	43_{8}	50_{1}	45_{1}
B 17	2421		19	31_{15}	34_{6}	36_{2}	...	...	41_{7}	50_{2}	...
A 25	2425	1895. Feb.	25	33_{4}	31_{6}	30_{2}	40_{3}	50_{3}	47_{3}	40_{1}	48_{2}
C 21	2458	Mar.	18	24_{12}	23_{2}	33_{5}	43_{1}	39_{3}	43_{3}	...	38_{2}
B 27	2460		18	31_{14}	38_{1}	...	40_{2}	42_{1}	39_{2}	...	43_{2}
B 31	2463		18	20_{10}	26_{12}	24_{3}	36_{1}	32_{4}	31_{4}	39_{2}	...

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1.	8·0.	Plate.	Notes.
36_3	...	36_3	40_4	35_1	...	...	41_3	Mawson	Much cloud about.
...	...	41_4	...	43_1	...	...	44_1	,,	Cloudy 1^h before.
43_1	...	44_1	46_1	...	80_1	...	...	,,	
...	40_1	50_2	50_1	...	35_1	44_1	49_2	,,	Cloudy before and after.
46_1	...	47_2	48_1	51_1	55_1	53_1	56_3	,,	
44_1	...	50_3	...	52_3	48_1	56_1	...	,,	
35_2	36_3	36_2	...	...	50_2	...	46_3	,,	
35_1	...	34_3	65_1	42_1	...	...	49_2	,,	
34_3	...	39_3	45_3	37_1	44_1	...	39_1	,,	
39_1	...	38_3	40_1	43_6	40_1	43_1	64_1	,,	Very windy.
44_2	30_2	43_1	45_1	49_1	...	...	...	,,	Violent wind.
36_1	...	50_1	44_1	45_1	47_1	48_1	...	,,	
39_2	24_1	...	...	51_3	...	...	...	,,	
...	40_1	...	...	51_3	38_1	...	45_2	,,	
28_1	23_1	48_2	61_2	59_1	51_1	...	40_1	,,	
41_3	53_2	40_3	74_1	...	48_3	53_2	51_1	,,	
...	...	45_3	...	62_1	43_2	...	71_1	,,	
...	...	50_3	56_1	39_2	61_1	51_1	54_2	Rocket	
46_3	...	52_2	...	47_1	46_2	55_1	42_3	Mawson	Sky suddenly overcast immediately after.
...	42_1	52_3	83_1	...	...	...	58_3	,,	
50_2	...	43_2	...	61_3	...	...	48_1	,,	
59_2	...	63_3	...	68_1	...	...	72_1	,,	
44_2	...	51_1	...	...	...	47_2	53_2	,,	Misty.
48_1	...	46_1	...	76_1	...	47_1	74_1	,,	
34_3	...	28_2	...	40_4	35_2	...	42_7	,,	Foggy.
51_2	54_2	69_2	...	...	47_3	...	...	,,	
30_1	...	41_1	...	65_1	43_3	55_1	...	,,	
44_1	...	44_2	40_1	49_3	...	65_1	...	,,	
46_1	42_1	43_2	54_2	...	...	...	...	,,	Cloudy before and after.
25_1	...	39_3	25_1	...	...	42_1	43_2	,,	Cloudy after.
...	33_1	50_1	...	...	...	...	44_1	,,	
52_1	...	47_4	...	...	...	78_1	81_2	,,	Very windy.
...	...	50_1	...	57_2	60_1	...	46_1	,,	
46_1	...	57_1	48_1	...	...	...	50_1	,,	
33_2	...	45_3	...	71_1	...	...	61_3	,,	
...	...	46_3	...	...	...	...	...	,,	
35_3	...	40_1	39_1	...	...	...	...	Rocket	

No. in Zone.	No.	Date		Mean Diameters of images of stars 9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9.	8·8.
		1895.									
B 33	2475	Mar.	22	21_{5}	21_{4}	23_{6}	29_{5}	...	29_{2}	...	32_{6}
A 35	2478		22	26_{8}	30_{8}	36_{3}	37_{2}	37_{3}	32_{4}	...	46_{1}
A 28	2495		28	27_{7}	30_{7}	38_{2}	38_{1}	46_{1}	43_{2}	41_{1}	42_{2}
A 36	2497		28	30_{9}	37_{2}	36_{4}	38_{4}	42_{1}	39_{3}	40_{1}	...
B 29	2499*		29	27_{11}	30_{7}	36_{4}	40_{1}	...	38_{3}	39_{2}	44_{3}
A 38	2502		29	22_{6}	32_{2}	32_{5}	37_{3}	42_{1}	43_{3}	...	40_{1}
B 40	2521	April	10	19_{4}	24_{5}	32_{2}	...	...	39_{3}	33_{1}	41_{3}
A 40	2522		10	20_{4}	27_{2}	27_{7}	42_{1}	...	40_{2}	37_{1}	31_{2}
C 38	2524		10	24_{12}	30_{1}	25_{3}	18_{1}	32_{4}	33_{3}	...	...
C 39	2525		10	27_{6}	27_{5}	37_{2}	...	24_{1}	32_{2}	34_{1}	...
B 44	2526		10	24_{6}	26_{9}	33_{3}	...	...	37_{2}	40_{2}	38_{3}
B 45	2537		14	31_{9}	32_{4}	40_{4}	...	41_{1}	38_{2}	...	47_{2}
C 35	2549		23	32_{3}	24_{2}	27_{3}	29_{3}	23_{2}	35_{2}	28_{1}	42_{2}
A 45	2554		23	21_{9}	33_{4}	28_{2}	30_{1}	37_{3}	40_{4}	40_{2}	...
A 47	2555		23	24_{10}	24_{5}	25_{3}	30_{4}	38_{1}	34_{3}	36_{2}	...
B 47	2557		23	25_{5}	37_{1}	...	24_{1}	32_{4}	28_{1}	38_{2}	38_{1}
B 49	2559		23	29_{8}	29_{3}	33_{3}	40_{1}	36_{2}	36_{3}	...	44_{2}
B 50	2560		23	25_{15}	22_{2}	40_{2}	...	35_{4}	...	34_{2}	35_{4}
A 48	2568		24	24_{7}	30_{2}	29_{4}	25_{1}	43_{1}	35_{1}	...	38_{1}
C 44	2569		24	25_{11}	28_{2}	39_{1}	29_{1}	33_{4}	31_{4}	...	35_{1}
C 45	2570		24	23_{10}	26_{3}	28_{2}	30_{3}	25_{5}	35_{2}	23_{1}	25_{1}
B 48	2593	May	4	24_{8}	30_{5}	35_{2}	34_{3}	...	39_{8}	36_{1}	64_{1}
C 46	2605		6	23_{7}	34_{3}	27_{2}	...	38_{1}	38_{8}	42_{4}	44_{1}
B 53	2606		6	31_{12}	35_{2}	56_{1}	34_{1}	40_{2}	64_{1}	40_{4}	50_{2}
A 50	2639		27	19_{12}	13_{1}	14_{3}	24_{3}	...	31_{4}	28_{2}	33_{3}
C 40	2641		29	27_{7}	26_{8}	35_{2}	36_{1}	47_{2}	51_{2}	...	45_{2}
B 55	2651	June	2	29_{8}	29_{1}	33_{2}	33_{6}	42_{1}	41_{5}	...	43_{3}
C 50	2652		2	28_{11}	30_{9}	37_{1}	45_{5}	44_{1}	54_{3}	44_{2}	44_{4}
B 51	2654		5	24_{10}	24_{2}	30_{2}	30_{2}	26_{3}	33_{3}	...	...
B 52	2655		5	25_{14}	26_{1}	24_{2}	...	32_{1}	36_{6}	34_{6}	37_{1}
A 53	2657		5	26_{18}	...	37_{4}	34_{1}	35_{5}	31_{5}	38_{1}	39_{1}
C 48	2658		5	28_{6}	32_{1}	...	28_{2}	31_{1}	35_{2}	...	38_{1}
B 54	2659		5	27_{10}	30_{3}	36_{1}	31_{1}	39_{2}	40_{1}	46_{1}	45_{2}
B 56	2660		5	29_{11}	33_{8}	42_{4}	38_{3}	...	42_{9}	43_{3}	43_{4}
B 58	2661		5	33_{10}	31_{5}	31_{2}	41_{3}	37_{2}	41_{1}	46_{1}	44_{1}
C 52	2662		5	28_{14}	35_{5}	29_{3}	37_{4}	35_{2}	38_{1}	47_{1}	...
A 59	2672		8	33_{11}	35_{3}	36_{7}	41_{5}	42_{4}	44_{3}	...	52_{1}
A 60	2673		8	32_{16}	31_{1}	33_{7}	34_{3}	38_{2}	42_{5}	38_{1}	38_{1}

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1.	8·0.	Plate.	Notes.
...	...	...	...	...	46_1	...	...	Rocket	Seeing bad at intervals.
45_2	...	43_3	36_1	54_1	(87_1)	40_1	42_2	Mawson	
...	...	44_2	...	40_4	...	53_2	46_1	Rocket	Shaken by wind.
40_2	...	40_1	...	61_4	...	...	44_1	„	
...	...	55_3	...	49_2	...	44_1	83_1	Mawson	Clouds interfered.
41_1	...	...	...	43_1	48_2	...	44_1	Rocket	Cloudy after.
...	...	44_1	...	34_1	...	...	38_2	„	
...	46_1	44_1	53_1	...	...	...	40_1	Mawson	
...	43_1	53_1	...	...	...	...	...	„	
40_1	...	40_1	...	...	...	...	...	Rocket	
40_1	...	51_1	...	44_1	...	...	...	„	
...	...	55_1	...	...	...	...	57_2	„	
41_1	...	43_1	50_2	42_4	...	...	60_1	Mawson	
...	39_3	...	...	42_2	...	...	55_2	Rocket	
40_1	36_1	...	37_1	...	...	...	...	Mawson	
...	47_3	...	52_2	...	...	...	49_2	„	Night uniformly good.
39_1	40_1	33_1	...	41_1	...	...	...	Rocket	
...	60_1	46_2	...	50_2	40_1	36_1	63_2	Mawson	
...	42_1	...	...	42_1	42_2	43_1	...	Rocket	
...	...	39_2	...	39_1	...	...	...	„	
...	...	41_1	...	...	42_1	...	40_1	„	
36_1	36_1	43_2	54_1	...	44_1	...	...	Mawson	
40_1	...	58_1	...	64_1	52_1	50_1	51_2	„	
44_1	...	70_1	...	...	...	...	...	„	
...	32_1	39_1	...	43_2	...	...	42_2	Rocket	Sky rather thick. Dew.
47_1	...	68_1	...	62_1	...	...	54_1	Mawson	
51_1	...	45_2	50_1	44_1	...	...	48_2	„	Thin clouds.
43_2	...	45_2	51_1	43_2	...	...	54_1	Rocket	
...	...	36_1	...	60_1	...	...	...	„	
40_2	...	47_2	...	...	...	...	34	„	
40_1	...	44_1	...	50_1	41_1	46_1	...	„	
43_2	40_1	42_1	...	54_1	41_1	...	51_2	„	
42_1	...	46_1	...	...	...	50_1	57_2	„	
41_2	...	47_1	...	...	50_1	...	58_2	„	
48_2	47_1	47_3	...	42_1	78_1	...	...	„	
37_3	39_1	42_3	46_2	45_2	68_1	...	49_1	„	
47_3	...	50_3	...	52_1	49_3	...	52_1	„	
43_3	...	...	...	...	...	...	56_1	„	

No. in Zone	No.	Date.	Mean Diameters of images of stars							
			9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9.	8·8.
C 53	2686	1895. June 16	25_{15}	25_{5}	30_{6}	31_{6}	...	31_{8}	...	42_{1}
C 54	2687	16	24_{12}	25_{2}	...	34_{6}	37_{3}	38_{8}	31_{1}	36_{2}
C 55	2688	16	28_{20}	32_{4}	34_{5}	39_{4}	38_{1}	38_{6}	40_{2}	...
B 62	2689	16	33_{10}	31_{8}	35_{2}	37_{5}	39_{5}	40_{6}	...	...
B 63	2690	16	32_{15}	33_{2}	31_{2}	37_{5}	42_{1}	43_{5}	47_{1}	42_{1}
C 57	2691	16	32_{14}	31_{6}	34_{6}	22_{1}	41_{6}	42_{3}	43_{1}	43_{2}
B 60	2696	17	27_{12}	27_{2}	34_{4}	33_{3}	37_{4}	42_{4}	33_{1}	33_{1}
A 61	2697	17	27_{12}	34_{5}	40_{1}	37_{5}	47_{1}	44_{8}	...	49_{2}
A 62	2700	17	36_{9}	33_{6}	39_{2}	41_{3}	44_{3}	45_{4}	48_{2}	...
A 68	2769	July 26	18_{10}	25_{8}	27_{4}	28_{4}	28_{4}	36_{6}	35_{2}	...
B 74	2777	Aug. 6	28_{45}	31_{8}	35_{6}	34_{3}	36_{3}	34_{9}	38_{5}	56_{1}
A 75	2831	Sept. 9	22_{21}	24_{12}	30_{10}	28_{9}	33_{3}	34_{7}	40_{2}	48_{3}
A 78	2834	9	26_{43}	32_{9}	35_{8}	34_{2}	40_{3}	41_{11}	56_{2}	46_{2}
A 76	2835	10	24_{18}	29_{13}	25_{5}	34_{14}	40_{5}	42_{5}	44_{1}	42_{2}
B 77	2837	10	22_{17}	32_{12}	31_{5}	34_{9}	39_{6}	39_{7}	43_{2}	...
B 76	2859	19	23_{18}	27_{18}	29_{5}	32_{4}	36_{3}	35_{8}	40_{2}	48_{2}
C 69	2860	19	22_{25}	28_{6}	34_{3}	29_{2}	33_{5}	32_{1}	44_{1}	40_{2}
B 1	2866	20	23_{29}	25_{7}	28_{4}	31_{8}	27_{4}	35_{8}	38_{3}	38_{1}
B 2	2867	20	23_{27}	28_{10}	29_{3}	30_{5}	34_{3}	29_{6}	40_{1}	40_{3}
B 4	2868	20	26_{16}	29_{9}	31_{5}	25_{6}	37_{2}	34_{7}	36_{2}	37_{4}
A 79	2902	Oct. 2	17_{26}	19_{12}	23_{7}	26_{6}	28_{8}	30_{5}	24_{5}	29_{2}
C 3	2918	16	20_{15}	28_{6}	27_{9}	30_{8}	35_{1}	35_{3}	25_{1}	34_{2}
B 5	2923	17	28_{13}	29_{10}	38_{2}	41_{2}	41_{3}	40_{5}	...	38_{2}
B 6	2947	Nov. 14	32_{34}	37_{10}	36_{7}	41_{6}	39_{6}	44_{5}	40_{2}	41_{2}
A 73	2950	17	20_{31}	25_{16}	25_{7}	...	27_{2}	32_{4}	34_{2}	30_{5}
C 10	2963	Dec. 3	26_{7}	31_{4}	36_{7}	31_{6}	31_{1}	39_{3}	43_{4}	48_{2}
A 12	2965	3	32_{5}	38_{8}	...	38_{1}	39_{1}	40_{6}	...	46_{6}
A 16	2967	10	26_{16}	30_{4}	28_{3}	24_{2}	36_{1}	32_{1}	46_{1}	39_{2}
A 17	2968	10	30_{17}	32_{7}	35_{4}	40_{1}	44_{2}	39_{3}	44_{2}	41_{2}
B 19	2979	1896. Jan. 17	33_{8}	29_{3}	28_{4}	27_{1}	36_{1}	40_{3}	56_{1}	39_{6}
A 14	2981	28	21_{9}	17_{2}	27_{3}	...	36_{1}	...	...	32_{2}
B 15	2986	Feb. 2	27_{9}	32_{1}	29_{5}	31_{8}	29_{3}	37_{3}	42_{1}	24_{1}
B 16	2987	2	18_{9}	26_{6}	33_{1}	26_{5}	21_{3}	33_{2}	...	31_{4}
C 12	2995	4	24_{9}	29_{6}	32_{6}	37_{4}	33_{1}	46_{1}	40_{1}	...
C 11	3015	22	18_{12}	19_{5}	26_{5}	22_{4}	15_{1}	25_{5}	30_{2}	25_{1}
A 19	3018	22	33_{13}	28_{2}	35_{2}	37_{4}	...	43_{2}	38_{2}	44_{9}
A 20	3019	22	26_{16}	30_{1}	36_{1}	...	40_{1}	39_{3}	...	...

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1.	8·0.	Plate.	Notes.
32_1	...	36_2	...	...	...	51_2	60_1	Rocket	
42_2	43_2	42_3	...	47_1	...	...	...	„	
...	41_2	38_1	...	43_1	...	...	57_1	„	Uniformly good night.
46_1	57_1	...	48_2	...	44_1	...	48_2	Mawson	
40_2	55_2	49_2	...	...	...	...	...	„	
41_1	55_4	55_1	...	...	...	...	...	„	
45_2	43_1	41_2	...	...	43_2	...	52_1	Mawson	
46_2	...	45_3	...	...	51_1	82_1	56_2	„	
43_1	52_2	52_1	46_2	...	...	...	48_1	„	
...	...	25_1	40_2	...	...	51_1	...	„	
44_2	43_3	46_3	...	45_1	48_3	50_3	...	„	Cloudy after.
45_3	43_1	42_1	54_1	53_2	...	...	60_4	Rocket	
56_1	...	44_1	42_1	58_3	49_2	...	40_2	„	
...	53_2	47_2	...	46_1	45_2	56_1	...	Mawson	
44_1	42_5	50_4	46_1	49_2	...	...	50_4	Rocket	
38_1	40_1	40_2	34_1	43_3	46_2	...	50_1	„	Misty low down
42_2	43_2	44_4	45_1	49_2	58_1	...	46_4	„	
44_4	30_1	49_4	42_2	50_1	42_5	43_1	53_2	„	
43_3	35_2	36_3	...	46_6	48_1	...	...	„	
...	...	46_1	42_2	51_1	44_1	46_1	45_2	„	
36_3	...	31_8	38_1	30_4	34_1	...	40_1	„	Wind S.W. Bright. Unsettled.
35_1	...	44_1	...	...	...	...	54_1	„	
53_1	...	51_2	52_1	...	44_1	...	49_2	„	
50_2	...	55_2	...	...	...	50_1	54_1	„	
...	35_3	38_7	29_2	28_2	...	42_1	...	„	
...	33_1	47_1	...	44_2	...	...	58_5	„	
47_1	...	55_2	...	...	...	60_1	59_2	„	Cloudy after.
...	...	44_2	...	...	...	...	44_1	„	
...	...	49_2	...	47_2	...	...	45_2	„	
...	28_1	...	...	...	...	...	47_2	„	
...	38_1	40_2	46_1	37_1	40_1	...	42_1	„	Sky misty.
30_2	40_1	42_1	...	38_1	40_1	43_3	...	„	
44_2	...	68_1	...	44_1	...	...	34_1	„	
38_1	...	...	...	...	...	...	64_1	„	
...	...	28_2	...	...	...	...	32_1	„	
38_1	...	...	...	...	...	...	52_1	„	
40_2	...	42_2	48_1	48_1	...	...	...	„	

No. in Zone.	No.	Date.	Mean Diameters of images of stars 9·5.	9·4.	9·3.	9·2.	9·1.	9·0.	8·9.	8·8.
		1896.								
C 24	3032	Mar. 19	26_{10}	31_{2}	...	34_{3}	28_{1}	31_{2}	...	37_{2}
B 22	3038	23	24_{7}	29_{3}	30_{1}	31_{2}	18_{1}	35_{5}	...	23_{1}
A 29	3041	23	31_{11}	32_{9}	38_{4}	40_{3}	38_{3}	37_{4}	...	...
B 38	3068	Apr. 10	30_{3}	35_{3}	33_{2}	40_{4}	...	41_{6}	...	42_{1}
C 31	3079	15	22_{15}	24_{4}	31_{8}	28_{1}	32_{2}	29_{2}	27_{2}	...
B 36	3104	28	31_{4}	33_{7}	33_{5}	38_{2}	58_{2}	49_{1}	...	...
C 32	3105	28	28_{6}	28_{4}	29_{4}	29_{1}	46_{1}	39_{3}	...	...
A 37	3123	May 4	30_{11}	42_{3}	38_{6}	30_{2}	38_{1}	38_{2}	...	36_{3}
B 80	3292	Oct. 29	19_{33}	18_{9}	25_{5}	28_{2}	27_{6}	26_{3}	27_{3}	...
		1897.								
B 28	3378	Mar. 3	26_{6}	32_{4}	32_{1}	36_{2}	28_{3}	48_{1}	...	36_{2}
		1898.								
C 36	3907	Mar. 20	31_{10}	39_{8}	...	40_{1}	...	42_{1}	42_{1}	42_{1}

§ 5. Dividing the plates into groups according to the diameters of the $9^m{\cdot}5$ stars, including in

Group 1, 22	plates	with mean	diameters of	$9^m{\cdot}5$ stars	15 to 19
„ 2, 31	„	„	„	„	20 „ 22
„ 3, 46	„	„	„	„	23 „ 25
„ 4, 49	„	„	„	„	26 „ 28
„ 5, 45	„	„	„	„	29 „ 31
„ 6 {30	„	„	„	„	32 „ 34
{8	„	„	„	„	35 „ 43

we find the following mean results for the several groups, weighted means being taken.

TABLE II.

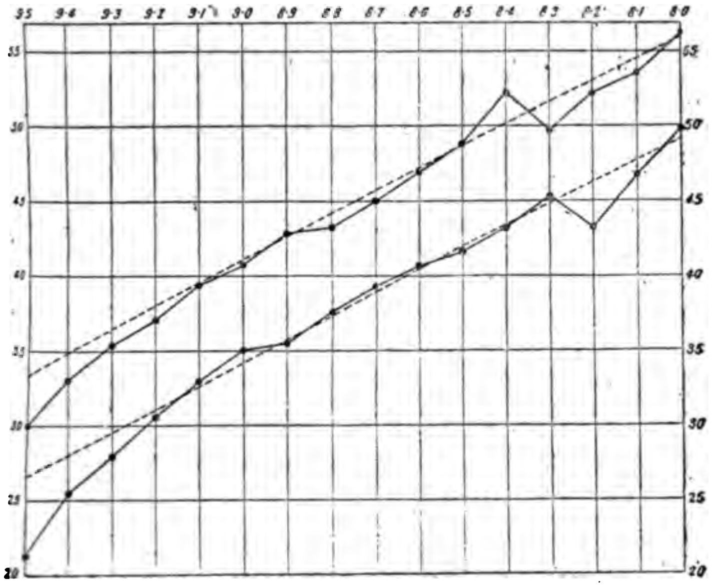
Group.	9·5	9·4	9·3	9·2	9·1	9·0	8·9	8·8
1	17·7	20·3	25·0	25·5	29·6	32·1	30·0	33·6
2	21·0	26·3	28·3	32·6	35·2	36·5	38·0	39·5
3	24·1	29·8	30·6	33·8	34·3	36·8	38·6	40·4
4	27·0	30·3	34·6	35·5	36·8	39·4	40·4	42·4
5	29·9	33·7	35·3	36·2	39·5	39·8	42·8	43·3
6	33·3	34·8	36·5	39·7	42·0	42·7	45·6	44·1

Group.	8·7	8·6	8·5	8·4	8·3	8·2	8·1	8·0
1	34·3	36·8	36·7	38·9	39·8	38·6	46·1	44·4
2	40·7	40·4	42·7	46·0	45·5	44·5	45·2	50·7
3	43·2	44·8	45·5	44·6	50·5	47·1	49·1	54·4
4	42·7	43·8	44·3	50·3	47·6	49·9	49·1	53·8
5	45·5	45·8	48·4	54·0	51·1	51·1	53·8	57·1
6	47·1	51·4	53·2	52·7	50·3	55·8	58·0	58·4

whose Magnitudes are given in the *B.D.*

8·7.	8·6.	8·5.	8·4.	8·3.	8·2.	8·1.	8·0.	Plate.	Notes.
21_1	...	40_3	...	...	...	...	...	Rocket	
38_1	...	42_2	38_1	36_2	...	...	...	"	Definition bad
...	45_2	50_1	...	47_2	...	...	60_1	"	
48_2	...	44_2	...	45_2	...	...	...	Ilford	
...	...	50_2	41_1	...	...	...	...	Rocket	
42_1	...	43_3	40_1	52_2	...	...	49_1	"	
...	...	44_1	...	...	...	...	...	"	
47_1	...	...	...	42_1	...	...	48_1	"	
32_2	28_1	38_1	40_1	30_1	34_1	30_1	34_2	"	
...	...	...	...	39_2	...	47_2	52_1	"	
...	...	59_1	...	...	...	...	61_1	Ilford	

The mean of the first three and second three are given in the diagram.



§ 6. The parallelism of the two curves in the diagram shows that the change in diameter for a magnitude is independent of the actual size of the diameters, the change of diameter for one magnitude being roughly 15.

They also show that between the limits $8^{m}\cdot5$ and $9^{m}\cdot2$ the relation between diameter and magnitude is fairly well represented by a linear formula. This extends to $8^{m}\cdot0$, though the discordances are large; as there are fewer stars of the brighter magnitudes, and their diameters are more affected by the position of the images on the plate, this is not surprising. The curves fall below the straight line for the mags. $9^{m}\cdot3$, $9^{m}\cdot4$ and $9^{m}\cdot5$, so that a magnitude $9^{m}\cdot8$ would be given by producing the straight line from $8^{m}\cdot0$ to $9^{m}\cdot2$ to the magnitude denominated $9^{m}\cdot5$ in the *B.D.*

§ 7. Returning to the six groups in § 5 and using only the images of stars of magnitudes $9^{m}\cdot2$ to $8^{m}\cdot0$ *B.D.* we find, solving by least squares

Group (1) $d=35\cdot9-(m-8\cdot6)\times14\cdot5$
,, (2) $d=41\cdot3-(m-8\cdot6)\times12\cdot5$
,, (3) $d=43\cdot3-(m-8\cdot6)\times15\cdot6$
,, (4) $d=44\cdot3-(m-8\cdot6)\times13\cdot9$
,, (5) $d=46\cdot8-(m-8\cdot6)\times15\cdot7$
,, (6) $d=49\cdot2-(m-8\cdot6)\times15\cdot8$

confirming what the diagrams showed, that the rate or parameter is not dependent on the magnitude of the diameters. Giving half weight to Groups (1) and (2), as they depend on a smaller number of plates, we find the mean value of the coefficient of $(m-8\cdot6)=14\cdot7$.

Using this value of the diminution of diameter per magnitude, we find the following as the diameters given by the formula for the several groups :—

	9·2	9·1	9·0	8·9	8·8	8·7	8·6	8·5	8·4	8·3	8·2	8·1	8·0
(1)	27·1	28·5	30·0	31·5	33·0	34·4	35·9	37·4	38·8	40·3	41·8	43·3	44·7
(2)	32·5	33·9	35·4	36·9	38·4	39·8	41·3	42·8	44·2	45·7	47·2	48·7	50·1
(3)	34·5	35·9	37·4	38·9	40·4	41·8	43·3	44·8	46·2	47·7	49·2	50·7	52·1
(4)	35·5	36·9	38·4	39·9	41·4	42·8	44·3	45·8	47·2	48·7	50·2	51·7	53·1
(5)	38·0	39·4	40·9	42·4	43·9	45·3	46·8	48·3	49·7	51·2	52·7	54·2	55·6
(6)	40·4	41·8	43·3	44·8	46·3	47·7	49·2	50·7	52·1	53·6	55·1	56·6	58·0

And comparing these with the measured values we find the following discordances :—

	9·2	9·1	9·0	8·9	8·8	8·7	8·6	8·5	8·4	8·3	8·2	8·1
(1)	+1·6	−1·1	−2·1	+1·5	−0·6	+0·1	−0·9	+0·7	−0·1	+0·5	+3·2	−2·8
(2)	−0·1	−1·3	−1·1	−1·1	−1·1	−0·9	+0·9	+0·1	−1·8	+0·2	+2·7	+3·5
(3)	+0·7	+1·6	+0·6	+0·3	0·0	−1·4	−1·5	−0·7	+1·6	−2·8	+2·1	+1·6
(4)	0·0	+0·1	−1·0	−0·5	−1·0	+0·1	+0·5	+1·5	−3·1	+1·1	+0·3	+2·6
(5)	+1·8	−0·1	+1·1	−0·4	+0·6	−0·2	+1·0	−0·1	−4·3	+0·1	+1·6	+0·4
(6)	+0·7	−0·2	+0·5	−0·8	+2·2	+0·6	−2·2	−2·5	−0·6	+3·3	+0·7	−1·4

These discordances seem quite accidental. They are somewhat large for the magnitudes 8·0 to 8·4, in one case amounting to 4·3, which corresponds to $0^m{\cdot}3$. Between $8^m{\cdot}5$ and $9^m{\cdot}0$ they only amount to $0^m{\cdot}1$ in seven cases out of forty-eight, and never amount to more than $0^m{\cdot}17$.

§ 8. As it is known that the *B.D.* magnitudes 9·5, 9·4, 9·3, are systematically made too bright in that work they were not used in the determination of the relation between diameter and magnitude. Since the *B.D.* mags. 9·3 to 9·5 are not near the limits of magnitude reached on the photographic plates, it seems quite legitimate to assume that the relation determined above may be extended by this amount.

Extrapolating the results in § 7 we obtain the following table giving the excess of the diameter given by the formula over the measured diameters of stars given in the *B.D.* as of mags. $9^m{\cdot}3$, $9^m{\cdot}4$, $9^m{\cdot}5$ respectively :—

	9·3	9·4	9·5	
Group 1	+0·6	+3·9	+5·0	Half weight
2	+2·7	+3·3	+7·1	
3	+2·4	+1·8	+6·0	
4	−0·6	+2·3	+4·1	
5	+1·2	+1·4	+3·5	
6	+2·4	+2·7	+2·5	
Mean	1·41	2·36	4·43	

The accordance of these groups in which the diameters of the $9^m{\cdot}5$ images are very different is satisfactory. The progressive diminution of the difference for $9^m{\cdot}5$ is probably due to the method of grouping, by which all the accidental errors making the 9^m 5 diameters larger tend to make the differences in groups smaller while those which make the diameters smaller tend to make the differences in the earlier groups larger. Had the arrangement been according to the $9^m{\cdot}0$ diameters this would not have occurred.

The above means indicate that on the same scale as the *B.D.* magnitudes from 8·0 to 9·2, *B.D.* $9^m{\cdot}3$ requires a correction $+0^m{\cdot}10$, *B D.* $9^m{\cdot}4$ a correction of $+0^m{\cdot}16$, and *B.D.* $9^m{\cdot}5$ a correction of $+0^m{\cdot}30$, so that these magnitudes should be $9^m{\cdot}40$, $9^m{\cdot}56$, and $9^m{\cdot}80$ respectively.

As these results are only derived by an extrapolation satisfying the magnitudes from $8^m{\cdot}0$ to $9^m{\cdot}2$, we do not attach much weight to them. Between such a limited range as $8^m{\cdot}0$ to $9^m{\cdot}2$ there is little difference between the various laws proposed connecting diameter and magnitude. Table I., whatever law may be found connecting diameter and magnitude, gives the data from which the constants for the plates must be found.

We proceed now to consider, irrespective of any law connecting magnitude and diameter,

(i) The constancy of the nominal *B.D.* $9^m\cdot5$ in different of the zone.

(ii) The differences between the three kinds of plates us

§ 9. To facilitate these further comparisons of the diff plates the stars were divided into a smaller number of group cording to magnitude in *B.D.* The groups chosen were $9\cdot5$ — $8\cdot7-9\cdot2$; and $8\cdot0-8\cdot6$. In the first group by far the l number of stars were of *B.D.* mag. $9^m\cdot5$; a correction of was applied to those of mag. $9^m\,4$, and of -6 to those of $9^m\cdot3$, thus reducing them all to *B.D.* $9^m\cdot5$, and the weig means taken. Similarly in the groups $8\cdot7-9\cdot2$ and $8\cdot0-8$ change in diameters of $1\frac{1}{2}$ in each $0^m\cdot1$ was applied, and means taken as giving the diameters corresponding to *B.D.* and *B.D.* $8^m\cdot3$, which (allowing for the larger number of fai stars in the groups) are nearest the means of the groups.

This is merely a convenient way of dividing the stars three groups, and the resulting figures give the observed meters of *B.D.* $9^m\cdot5$, $9^m\cdot0$, and $8^m\cdot3$, and are only depende an infinitesmal extent on the corrections applied.

The plates are arranged in order of right ascension in three zones, 65°, 66°, 67°.

TABLE III.

No. of Plate.	Mean diameter corresponding to *B.D.* Mag. $9^m\cdot5$.	$9^m\cdot0$.	$8^m\cdot3$.	$9^m\cdot0-9^m\cdot5$.	$8^m\,3-9^m\,0$.	No. of Plate.	Mean diameter correspondin to *B.D.* Mag $9^m\cdot5$.	$9^m\cdot0$	$8^m\cdot3$.	$9^m\,0-$ 8 $9^m\,0$.
2376	15_{15}	27_{21}	37_{15}	12	10	807	33_{10}	45_{8}	51_{4}	12
2287	27_{42}	41_{16}	52_{13}	14	11	1653	42_{3}	46_{18}	47_{6}	4
1631	21_{38}	40_{29}	54_{8}	19	14	1654	35_{15}	52_{6}	58_{5}	17
1632	24_{42}	43_{22}	53_{7}	19	10	1774	35_{18}	46_{10}	58_{3}	11
2334	31_{58}	40_{20}	58_{7}	9	18	2425	25_{13}	46_{13}	52_{3}	21
1633	24_{48}	41_{28}	55_{7}	17	14	849	28_{13}	39_{9}	43_{5}	11
2380	32_{43}	44_{20}	57_{7}	12	13	850	18_{17}	27_{14}	33_{1}	9
2323	24_{28}	36_{14}	51_{11}	12	15	2495	28_{16}	41_{9}	45_{10}	13
1610	30_{31}	44_{11}	50_{7}	14	6	3041	31_{24}	40_{13}	50_{7}	9
1640	27_{21}	43_{16}	57_{6}	16	14	852	27_{22}	42_{13}	49_{2}	15
748	30_{18}	41_{9}	51_{7}	11	10	853	25_{18}	37_{8}	47_{3}	12
2965	33_{8}	41_{12}	56_{7}	8	15	854	24_{20}	35_{11}	42_{5}	11
2367	32_{20}	46_{13}	67_{5}	14	23	855	26_{21}	39_{9}	54_{1}	13
2981	20_{14}	32_{4}	41_{7}	12	9	856	31_{20}	37_{8}	45_{5}	6
2369	24_{28}	42_{41}	46_{5}	18	4	2478	28_{13}	37_{13}	43_{8}	9
2967	26_{21}	34_{7}	47_{4}	8	13	2497	31_{15}	39_{11}	54_{6}	8
2968	30_{28}	41_{10}	44_{4}	11	3	3123	32_{20}	36_{0}	43_{2}	4
1650	27_{24}	45_{12}	66_{3}	18	21	2502	25_{13}	41_{8}	44_{4}	16
3018	32_{17}	40_{12}	57_{1}	8	17	331*a*	23_{17}	38_{12}	58_{3}	15
3019	26_{18}	38_{6}	47_{4}	12	9	2522	21_{11}	38_{5}	47_{4}	17

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
336	25_{7}	32_{9}	44_{4}	7	12
2022	25_{15}	38_{18}	49_{5}	13	11
345	20_{15}	30_{10}	43_{6}	10	13
1995	31_{14}	50_{5}	57_{2}	19	7
2554	24_{13}	38_{10}	46_{8}	14	8
346	16_{9}	31_{11}	43_{5}	15	12
2555	23_{18}	34_{11}	40_{2}	11	6
2568	24_{12}	35_{4}	42_{5}	11	7
2074	28_{22}	41_{7}	42_{4}	13	1
2639	17_{16}	29_{12}	40_{10}	12	11
359	21_{17}	34_{10}	39_{4}	13	5
2044	22_{18}	36_{12}	57_{4}	14	21
2657	27_{22}	34_{14}	45_{4}	7	11
2046	23_{15}	40_{9}	50_{5}	17	10
423	29_{13}	37_{17}	45_{6}	8	8
392	34_{22}	44_{8}	54_{3}	10	10
437	32_{23}	46_{15}	55_{3}	14	9
2048	28_{22}	40_{10}	51_{3}	12	11
2672	33_{21}	44_{16}	50_{8}	11	6
2673	30_{24}	39_{15}	51_{1}	9	12

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
2697	29_{18}	44_{20}	54_{7}	15	10
2700	34_{17}	44_{13}	50_{6}	10	6
1321	17_{32}	24_{13}	36_{4}	7	12
1274	25_{25}	37_{19}	45_{7}	12	8
534	28_{29}	34_{17}	44_{6}	6	10
426	24_{41}	35_{18}	47_{9}	11	12
2270	21_{23}	34_{15}	43_{6}	13	9
2769	19_{31}	33_{16}	41_{4}	14	8
2280	24_{33}	41_{18}	46_{8}	17	5
535	27_{31}	36_{20}	42_{6}	9	6
536	31_{41}	38_{29}	43_{12}	7	5
1334	31_{27}	37_{29}	48_{22}	6	11
2950	20_{34}	31_{14}	37_{15}	11	6
1593	23_{40}	37_{16}	48_{9}	14	11
2831	22_{43}	37_{27}	52_{9}	15	15
2835	24_{36}	37_{27}	50_{8}	13	13
1613	20_{44}	35_{23}	47_{11}	15	12
2834	27_{60}	44_{21}	48_{9}	17	4
2902	17_{45}	28_{29}	36_{12}	11	8
1656	20_{33}	32_{19}	44_{7}	12	12

Zone 66°.

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$3^{m}\cdot3-9^{m}\cdot0$
2866	23_{10}	35_{23}	45_{16}	12	10
2867	24_{10}	33_{19}	43_{12}	9	10
1681	26_{33}	44_{20}	61_{1}	18	17
2868	26_{30}	35_{21}	44_{8}	9	9
2923	27_{30}	42_{13}	49_{6}	15	7
2947	33_{31}	42_{24}	53_{5}	9	11
658	24_{25}	36_{12}	45_{6}	12	9
2382	27_{28}	39_{17}	48_{6}	12	9
1691	19_{21}	38_{11}	47_{7}	19	9
2404	29_{21}	42_{9}	49_{5}	13	7
724	19_{15}	25_{7}	41_{10}	6	16
2418	30_{15}	40_{11}	43_{3}	10	3
2419	32_{15}	42_{14}	61_{7}	10	19
2370	31_{20}	44_{6}	60_{4}	13	16

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
2986	26_{15}	33_{18}	40_{7}	7	7
2987	20_{16}	29_{16}	50_{3}	9	21
2421	31_{23}	43_{9}	53_{5}	12	10
1762	36_{18}	44_{10}	64_{4}	8	20
2979	29_{14}	38_{12}	39_{3}	9	1
797	33_{12}	48_{11}	...	15	...
786	36_{15}	44_{6}	69_{7}	8	25
3038	25_{11}	32_{10}	41_{6}	7	9
776	34_{14}	40_{16}	52_{12}	6	12
813	23_{12}	37_{6}	44_{4}	14	7
763	29_{20}	40_{7}	44_{2}	11	4
726	24_{9}	31_{11}	40_{10}	7	9
2460	30_{16}	41_{7}	49_{3}	11	8
3378	27_{11}	35_{8}	43_{5}	8	8

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag.					No. of Plate.	Mean Diameters corresponding to *B.D.* Mag.				
	$9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$		$9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
2499*a*	28_{22}	39_{9}	57_{7}	11	18	2651	29_{11}	36_{17}	46_{6}	7	10
872	30_{29}	39_{11}	52_{4}	9	13	2660	31_{23}	39_{21}	51_{3}	8	12
2463	21_{25}	33_{13}	48_{11}	12	15	427	10_{22}	19_{10}	38_{3}	9	19
899	28_{25}	39_{6}	49_{5}	11	10	2661	31_{17}	40_{10}	53_{6}	9	13
2475	19_{15}	30_{13}	47_{1}	11	17	446	31_{21}	43_{12}	53_{5}	12	10
951	26_{16}	38_{7}	46_{6}	12	8	2696	27_{18}	37_{17}	44_{6}	10	7
325	27_{28}	40_{2}	44_{4}	13	4	441	24_{28}	34_{14}	48_{3}	10	14
3104	30_{16}	48_{6}	47_{7}	18	1	2689	31_{20}	40_{13}	48_{6}	9	8
322	33_{14}	41_{11}	47_{7}	8	6	2690	31_{19}	41_{14}	56_{5}	10	15
3068	30_{14}	42_{13}	46_{4}	12	4	443	32_{32}	41_{13}	53_{7}	9	12
938	20_{12}	30_{7}	36_{4}	10	6	444	29_{28}	40_{16}	52_{10}	11	12
2521	21_{11}	36_{5}	53_{2}	15	17	1236	36_{37}	42_{16}	55_{7}	6	13
940	18_{19}	29_{3}	38_{3}	11	9	2290	24_{39}	33_{18}	52_{6}	9	19
941	22_{16}	32_{8}	42_{5}	10	10	2338	26_{22}	42_{11}	54_{6}	16	12
942	26_{4}	36_{14}	53_{5}	10	17	2279	25_{37}	38_{20}	58_{3}	13	20
2526	24_{20}	37_{6}	50_{2}	13	13	2308	21_{32}	37_{19}	42_{5}	16	5
2537	31_{17}	41_{4}	54_{3}	10	13	522	30_{47}	41_{22}	55_{3}	11	14
962	28_{10}	41_{9}	62_{3}	13	21	1587	28_{33}	35_{26}	50_{10}	7	15
2557	26_{8}	33_{9}	50_{7}	7	17	1588	27_{52}	37_{19}	56_{16}	10	19
2593	27_{16}	39_{9}	46_{5}	12	7	2777	26_{59}	37_{23}	48_{13}	11	11
2559	28_{14}	38_{9}	41_{3}	10	3	2283	26_{46}	40_{13}	51_{7}	14	11
2560	25_{19}	41_{21}	50_{9}	16	9	2859	23_{41}	37_{13}	43_{10}	14	6
2654	24_{14}	33_{9}	50_{2}	9	17	2837	24_{34}	36_{25}	43_{18}	12	7
2655	24_{17}	41_{16}	50_{2}	17	9	559	28_{38}	41_{21}	53_{9}	13	12
2606	32_{15}	43_{11}	73_{1}	11	30	2303	19_{36}	32_{14}	43_{13}	13	11
2659	27_{14}	40_{8}	50_{4}	13	10	3292	19_{47}	28_{17}	33_{8}	9	5

Zone 67°.

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag.					No. of Plate.	Mean Diameters corresponding to *B.D.* Mag.				
	$9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$		$9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
1548	26_{30}	41_{17}	46_{12}	15	5	1641	25_{9}	39_{11}	56_{2}	14	17
1549	31_{30}	44_{11}	53_{8}	13	9	2963	28_{18}	38_{16}	49_{9}	10	11
2918	21_{29}	33_{23}	48_{2}	12	15	3015	18_{22}	24_{13}	30_{3}	6	6
2406	17_{22}	28_{10}	38_{8}	11	10	2995	25_{21}	39_{8}	60_{1}	14	21
587	26_{39}	33_{14}	51_{7}	7	18	1645	31_{16}	44_{19}	59_{10}	13	15
1598	32_{30}	43_{15}	62_{9}	11	19	1646	32_{14}	43_{15}	63_{8}	11	20
1634	23_{27}	40_{17}	52_{6}	17	12	1647	28_{22}	38_{3}	57_{3}	10	19
703	18_{21}	36_{17}	44_{8}	18	8	1648	20_{18}	32_{12}	51_{10}	12	19

No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$	No. of Plate.	Mean Diameters corresponding to *B.D.* Mag. $9^{m}\cdot5$	$9^{m}\cdot0$	$8^{m}\cdot3$	$9^{m}\cdot0-9^{m}\cdot5$	$8^{m}\cdot3-9^{m}\cdot0$
1759	36_{13}	41_{9}	74_{3}	5	33	2570	23_{15}	30_{13}	40_{3}	7	10
1649	33_{15}	42_{9}	63_{6}	9	21	2605	24_{13}	39_{14}	53_{18}	15	14
1708	29_{16}	46_{8}	57_{6}	17	11	397	37_{15}	49_{16}	65_{1}	12	16
1747	33_{21}	42_{16}	55_{3}	9	13	2658	28_{7}	34_{8}	46_{6}	6	12
2458	25_{19}	41_{16}	55_{7}	16	14	419	28_{16}	41_{9}	52_{2}	13	11
1710	28_{15}	44_{7}	49_{5}	16	5	2652	28_{21}	45_{17}	48_{6}	17	3
792	30_{11}	40_{12}	50_{10}	10	10	2056	35_{20}	46_{11}	61_{8}	11	15
3032	26_{12}	32_{9}	43_{3}	6	11	2662	28_{22}	38_{11}	45_{12}	10	7
877	26_{12}	35_{9}	43_{7}	9	8	2686	24_{28}	33_{14}	46_{5}	9	13
1899	32_{24}	42_{7}	60_{4}	10	18	2687	24_{14}	36_{23}	46_{6}	12	10
1885	29_{24}	41_{5}	...	12	...	2688	28_{29}	39_{13}	45_{5}	11	6
811	28_{11}	38_{15}	46_{6}	10	8	2148	31_{8}	40_{8}	52_{2}	9	12
1863	33_{17}	42_{9}	54_{5}	9	12	2691	31_{28}	40_{14}	61_{4}	9	21
1932	33_{11}	41_{6}	55_{13}	8	14	2288	20_{45}	33_{22}	43_{9}	13	10
3079	22_{23}	30_{7}	49_{3}	8	19	2289	21_{44}	33_{13}	45_{7}	12	12
3105	26_{14}	39_{5}	47_{1}	13	8	2251	18_{40}	31_{17}	39_{11}	13	8
859	30_{13}	37_{7}	44_{5}	7	7	1416	33_{22}	46_{9}	56_{3}	13	10
1921	33_{11}	43_{13}	59_{6}	10	16	2310	22_{25}	35_{21}	47_{5}	13	12
2549	26_{8}	33_{12}	45_{8}	7	12	2311	17_{32}	30_{14}	44_{3}	13	14
3907	32_{13}	41_{4}	59_{2}	9	18	2312	21_{31}	33_{19}	45_{6}	12	12
862	28_{14}	38_{3}	44_{7}	10	6	2313	17_{47}	31_{20}	50_{8}	14	19
2524	24_{16}	32_{8}	52_{2}	8	20	2316	28_{44}	35_{28}	50_{11}	7	15
2525	27_{13}	32_{5}	43_{1}	5	11	2331	32_{30}	48_{20}	50_{9}	16	2
2641	26_{17}	45_{8}	60_{3}	19	15	2397	27_{24}	41_{23}	49_{6}	14	8
865	28_{9}	43_{8}	62_{3}	15	19	2860	23_{34}	35_{11}	49_{13}	12	14
2033	24_{10}	37_{14}	47_{12}	13	10	660	10_{22}	20_{12}	30_{12}	10	10
2034	24_{15}	38_{8}	48_{5}	14	10	556	28_{43}	37_{17}	49_{11}	9	12
2569	26_{14}	32_{10}	41_{3}	6	9	2333	26_{40}	45_{22}	45_{9}	19	0

When the weighted means are taken for the 27 plates in each three hours of right ascension we find

R.A. h h	$9^{m}\cdot5$.	No.	$9^{m}\cdot0$	No.	$8^{m}\cdot3$.	No.	$9^{m}\cdot0-9^{m}\cdot5$.	$8^{m}\cdot3-9^{m}\cdot0$.	Diff.
0–3	26·3	976	38·6	492	49·0	217	12·3	10·4	+1·9
3–6	27·9	492	39·1	307	52·2	146	11·2	13·1	−1·9
6–9	29·1	465	39·8	293	50·0	151	10·7	10·2	+0·5
9–12	27·2	465	38·1	255	48·0	145	10·9	9·9	+1·0
12–15	24·6	409	35·3	269	46·6	135	10·7	11·3	−0·6
15–18	27·2	529	39·2	370	50·1	138	12·0	10·9	+1·1
18–21	24·8	866	36·9	457	47·7	162	12·1	10·8	+1·3
21–24	24·4	1168	36·1	595	45·4	306	11·7	9·3	+2·4

§ 10. In the first 12 hours the diameters are systematically greater than in the second 12 hours.

	$9^m.5$.	$9^m.0$.	$8^m.3$.
$0^h - 12^h$	27·6	38·9	49·8
$12^h - 24^h$	25·2	36·6	47·5
	2·4	2·3	2·3

This difference may be due to meteorological conditions, the plates from $0^h - 12^h$ being photographed in the winter. As the plates are subjected to a preliminary examination to see whether an exposure of 20^s shows $9^m.0$ stars of Argelander's scale, it is natural that the difference between the plates taken at different times of the year should be small.

The table given above appears to show a greater difference between the magnitudes $9^m.0$ and $9^m.5$ of the *Bonn Durchmusterung* in the dense part of the zone from 18^h to 3^h than in the remainder. This difference may be accidental. When the means of the differences in Table III. are taken with equal weight we find

	$0^h - 3^h$.	$3^h - 6^h$.	$6^h - 9^h$.	$9^h - 12^h$.	$12^h - 15^h$.	$15^h - 18^h$.	$18^h - 21^h$.	$21 - 21^h$.
$9^m.0 - 9^m.5$	13·0	11·1	10·9	10·6	11·6	11·2	11·8	11·8
$8^m.3 - 9^m.0$	11·3	11·7	10·6	10·3	11·0	11·1	10·8	9·9
Diff.	+1·7	−0·6	+0·3	+0·3	+0·6	+0·1	+1·0	+1·9

Taking these differences as real, if they are due to systematic errors in the *Durchmusterung*, they indicate that *B.D.* $9^m.5$ represents a star fainter by about $0^m.1$ in the denser portions of the zone than in the remainder, or that *B.D.* $9^m.0$ indicates a star $0^m.1$ brighter in the denser part of the zone. The latter would seem the more probable explanation.

§ 11. As the Ilford, Mawson, and Rocket plates were used in each case for a whole year it is possible to obtain a fair comparison between them.

The diameters of the images of mags. $9^m.5$, $9^m.0$, $8^m.3$, are as follows, simple means being taken for the different plates :—

	$9^m.5$.	$9^m.0$.	$8^m.3$.
Ilford	27·0	37·2	47·6
Mawson	27·4	40·0	52·1
Rocket	25·0	35·5	45·6

The change in the size of the image between the limits 9·5 – 9·0 and 9·0 – 8·3 are as follows :—

	9·0–9·5.	8·3–9·0.	No. of plates.
Ilford	10·2	10·4	48
Mawson	12·6	12·1	117
Rocket	10·5	10·1	65

The Ilford and Rocket plates are thus alike, and show a change of 20·6 in diameter between the magnitudes 8·3 – 9·5,

while the Mawson plates show a difference of 24·7. Taking this interval as $1^{m}\cdot5$, the change in diameter for $1^{m}\cdot0$ in an Ilford or Rocket plate is 13·9, and in a Mawson plate 16·5.

§ 12. When the figures given in Table III. are rearranged for the different kinds of plates used, and in order of number and date as in Table I., it is seen that the differences of diameter for one magnitude or the parameters for the plates are very constant. There are very few cases in which the data would give them as outside the limits 13 to 15 for Ilford and Rocket plates, or 15 and 18 for the Mawson plates. This is very satisfactory, as it means that there is only one constant to be determined for each plate, and the determination of magnitude from diameter is thus rendered more certain.

Observations of Mars during the Apparition of 1898–99.
By the Rev. T. E. R. Phillips.

Observations of *Mars* were commenced at Yeovil at the beginning of September and continued till the end of April. On the whole the apparition was a tolerably favourable one, despite the smallness of the planet's disc, the number of nights when useful observations could be made showing a decided increase on the corresponding number during the previous apparition.

The powers usually employed were 217, 279, and on a few really good nights 312 on a 9¼-inch silvered glass Newtonian reflector.

In the following notes, after a brief discussion of the polar regions, the various features of the disc are dealt with in four sections, according to longitude. The nomenclature adopted is that of Signor Schiaparelli.

1. *Polar Regions.*

Throughout the apparition the N. Pole was presented to the Earth, the latitude of the centre of the disc about the time of opposition being approximately +12°.

N. Polar Cap.—This cap was very large and intensely bright. At times it appeared to have a slightly bluish colour, probably the effect of contrast with the reddish-ochre tone of the disc. The outline of the cap was fairly regular, and its edge always sharply defined in good air, and generally bounded by a dark blue-grey band. At the close of the observations in April the N. Polar Cap was still a bright and conspicuous object.

S. Polar Cap.—The tilt of the planet's N. hemisphere towards the Earth rendered the cap invisible, but a whitish glimmer was frequently observed illuminating the S. limb.

2. *Surface Markings between Longitudes* 0° *and* 90°.

Fastigium Aryn and *Margaritifer Sinus* were very clearly defined. *Deucalionis Regio* was quite distinct, and *Pyrrhæ Regio*

well observed on several occasions. The *Mare Acidalium* was very dark, though perhaps scarcely of that inky blackness which rendered it so conspicuous during the previous apparition. *Niliacus Lacus* was well seen, and united with Dawes's forked bay and *Margaritifer Sinus* respectively by the "canals" *Gehon* and *Indus*. *Achillis Pons* was noted in January, but became invisible later.

On March 1 a new lake was detected S.E. of *Niliacus Lacus*, uniting apparently the *Indus* and *Gehon* (fig. 2).

On March 2 and 3 the *N. Polar Cap* seemed to be sharply cut off at its f. end by an extension of the *Mare Acidalium* stretching away in a N.W. direction.

Auroræ Sinus was very dark. The *Jamuna* was usually invisible or exceedingly faint, but on March 1, in good air, it came out as a narrow and well-defined line (fig. 2). The *Ganges* on the whole was less prominent than during the apparition of 1896–97, but became very distinct about the middle of February. *Lacus Lunæ* was dark and fairly definite throughout the apparition.

The "canal" *Nilokeras* often appeared double, but anomalously as during the previous apparition. This does not seem to have been a case of optical gemination, but in all probability there are here two distinct "canals" almost meeting together at the *Lacus Lunæ*. On February 24 the *Nilokeras* appeared as a very broad dusky shading, but well defined and dark on its N. side (fig. 3). *Tempe* was seen intensely white on January 14, perhaps snow or fog.

An exceedingly white spot, fully as bright as the Polar Cap, was seen towards the end of February in about latitude −50°. This spot is evidently to be identified with the island of *Argyre*.

Lacus Tithonius and *Agathodæmon* were very well seen. *Lacus Solis* with rare exceptions was exceedingly difficult throughout the apparition, probably in consequence of the tilt of the planet's axis. The lake was seen best on February 14, when it came out quite clearly at times (fig. 4).

3. *Markings between Longitudes* 90° *and* 180°.

A dusky diffused spot was seen at times at S. end of *Ceraunius*. The f. end of this spot was apparently united with *Propontis* by the "canal" *Pyriphlegethon*. *Propontis* was very dark and clearly separated from the blue-grey band surrounding the N. Polar Cap (fig. 6).

The *Mare Sirenum* was decidedly dark and well-defined, with *Atlantis* quite distinct. *Phætontis* was intensely brilliant, and appeared at times by irradiation to indent the *Mare Sirenum*.

The "canal" *Eumenides-Orcus* was seen on favourable occasions as a very faint straight streak crossing the disc somewhat obliquely. Here and there diffused dusky spots were seen upon it. The most prominent of these was probably *Ammonium*

at the point where the *Eumenides-Orcus* is crossed by the *Titan.* The *Titan*, though seen occasionally extending N. from *Propontis*, was never traced quite so far as *Ammonium*, being decidedly fainter than during the previous apparition. The *Nodus Gordii* was indicated by a very faint diffused dusky patch best seen on January 4.

4. *Markings between Longitudes* 180° *and* 270°.

The *Trivium Charontis* was a very conspicuous object with the "canals" *Cerberus*, *Læstrygon*, *Orcus*, *Erebus*, *Hades*, and *Styx* radiating from it. The region between the two latter "canals" was rather darkly shaded, the shading extending right round the N. of *Elysium* to the region of *Aetheria* and the *Boreosyrtis* (figs. 7, 8, and 9). *Elysium* was decidedly white at times, and on a few occasions a brilliant spot was seen immediately f. the *Trivium Charontis.* On February 1 this bright region when at the limb shone with all the intensity of the Polar Cap. The *Galaxias* was well seen once or twice dividing Elysium into two parts. *Hyblæus* was very faint, and appeared to be the boundary line between the whiteness of *Elysium* and the dusky shading of *Aetheria* rather than a definite "canal." The *Cerberus* and *Cyclops* were very broad and dark, especially the former (figs. 8 and 9).

The *Mare Cimmerium* was well defined, with *Hesperia* quite distinct though narrow. *Hesperia* was seen as late as March 14.

Electris was very white at times, especially at the limb.

One of the most remarkable features exhibited by *Mars* during the last apparition was the large dark region in the neighbourhood of the *Boreosyrtis.* A new "lake" was detected here during the apparition of 1896–97, but by last winter this lake had swollen enormously, and was quite a prominent feature of the disc (figs. 9 and 10). *Mare Tyrrhenum* was very dark, even when close to the limb. The *Amenthes*, connecting the *Boreosyrtis* with the *Syrtis Minor*, was very well seen on several occasions.

Hephæstus was very difficult, but appeared occasionally as an exceedingly faint, ill-defined, dusky patch

5. *Markings between Longitudes* 270° *and* 360°.

There was a faint shading between the *Nilosyrtis* and *Boreosyrtis.* This shading was bounded on the west by *Colæ Palus*, and on the east by the unnamed "canal" which came out so prominently during the previous apparition between the N. extremity of the *Syrtis Major* and the *Borcosyrtis.* Last apparition this "canal" lost much of its distinctness, but the *Nilosyrtis* was seen very dark and sharply defined, especially on January 30.

The *Nepenthes* was glimpsed on a few occasions, and on February 1, during an interval of superb definition, a small spot

was seen upon it, probably at its junction with Thoth (invisible). This spot was again seen on February 2, and is perhaps to be identified with *Lacus Tritonis* (fig. 10). There was a curious "bridge" or rift just N. of the *Astusapes* which appeared to sever the *Nilosyrtis* from the *Syrtis Major* (fig. 11). This was seen distinctly when the seeing was good. The *Syrtis Major* was of a deep blue-grey tone, with at times a tinge of green. It was, as usual, very much darker towards its N. extremity. *Œnotria* was very distinct towards the end of January.

Libya was seen whitish, with a white "bridge" extending from it in a N.W. direction. Another "bridge" was observed running N.E. from *Pharos Insula*; but it was doubtful whether either of them really reach *Hellas* (fig. 11).

Hellas (always seen obliquely) was very white, especially when at the limb.

Sinus Sabæus was very dark, with *Xisuthri Regio* perfectly visible at times, though somewhat difficult.

Edom Promontorium was whitish, and frequently seemed to cast a glimmer of light across the *Sinus Sabæus*, almost severing it from Dawes's forked bay. *Ismenius Lacus*, and the "canals" *Astusapes*, *Astaboras*, *Phison*, *Euphrates*, *Orontes*, *Hiddekel*, and *Gehon*, were all well observed.

Summary.—Apart from the apparent changes caused by the greater tilt of the planet's N. hemisphere towards the Earth, and the diminution of the planet's angular diameter, the features of the disc showed but little alteration from their appearance in 1896–97. The most striking change was the great development of the dark spot seen on the *Boreosyrtis* in 1896.

Another point worthy of notice was the remarkable faintness of the markings near the centre of the disc, between longitudes 100° and 180° approximately. At times this region appeared almost entirely blank, though *Propontis* and the *Mare Sirenum* were decidedly dark.

As regards the so-called "canals," about forty of these objects were seen, or about twenty less than during the previous apparition. The difference is no doubt due to the diminution in the planet's angular diameter. No "canals" were seen certainly double except the *Nilokeras*; but in this case the two components were not parallel, and the writer feels quite convinced of the existence of two separate and distinct "canals." The *Nilokeras*, and the faint line inclined to it at an angle of about 20°, appeared exactly as during the apparition of 1896–97. On one occasion the *Eumenides-Orcus* was for a moment or two doubled, together with the *Trivium Charontis*. The effect, however, was very transitory, and was evidently an optical illusion caused perhaps by the passing of air-waves or by a temporary alteration of the focus of the eye. In poor seeing the "canals" were either totally invisible or were seen as broad, faint, diffused

2 3

Jan. 19.
$\phi = +11^{\circ}\cdot 5$.

March 1.
$\lambda = 32^{\circ}$ $\phi = +8^{\circ}\cdot 9$.

Feb. 24.
$\lambda = 62^{\circ}$ $\phi = +8^{\circ}\cdot 6$.

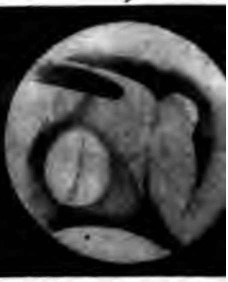
4 5 6

Feb. 14.
$\lambda = 91^{\circ}$ $\phi = +8^{\circ}\cdot 7$.

Jan. 8.
$\lambda = 118^{\circ}$ $\phi = +13^{\circ}\cdot 2$.

Jan. 4.
$\lambda = 153^{\circ}$ $\phi = +13^{\circ}\cdot 8$

7 8 9



Dec. 31.
$\lambda = 180^{\circ}$ $\phi = +14^{\circ}\cdot 4$.

Feb. 1.
$\lambda = 210^{\circ}$ $\phi = +9^{\circ}\cdot 7$.

Feb. 1.
$\lambda = 243^{\circ}$ $\phi = +9^{\circ}\cdot 7$.

10 11 12

streaks. In really good air they were much narrower and darker, and in some cases very definite and sharply defined.

No bright projections were seen either at the limb or terminator. Bright regions like *Argyre*, *Phætontis*, &c., &c. appeared at times to project slightly beyond the limb, but such effects were clearly ordinary irradiation phenomena.

During the apparition thirty-six whole disc drawings were made, twelve of which are reproduced on the accompanying plate (Plate 3).

Observations of Jupiter and his Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1898–99. By Joseph Gledhill.

The following observations of the physical features presented by the planet *Jupiter* during the opposition 1898–99 were made with the 9-inch Cooke Equatorial Refractor (photo-visual), and a Simms parallel-wire micrometer. The negative eye-pieces generally used had powers of 240 and 330; the power used with the micrometer was 280. The observing conditions were very seldom good and the number of clear nights was very small.

The results are arranged under the following heads:—

I. A description of the principal features seen on the disc of the planet.

II. Transits of the dark and bright spots &c. across the central meridian.

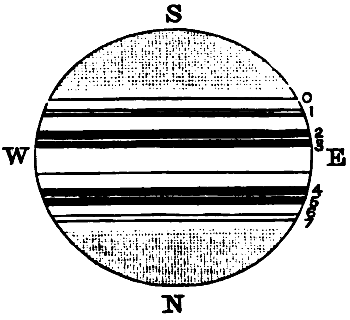
III. Measures.

Latitudes of the dark bands.
Widths of the dark bands and bright zones.
Summary 1895–96 to 1898–99.

IV. Notes on the satellites and their shadows.

V. Phenomena of the satellites.

As will be seen from the diagram, the dark bands are numbered 0, 1, 2, 3, 4, 5, 6, 7. Of these 2 and 3 form the



southern boundary of the coloured central zone, and 4, 5 form its boundary on the north. In terms of the nomenclature of the *British Astronomical Association*, 0 is the *Southern South Temperate Band*, 1 is the *South Temperate Band*, 2 and 3 form the *South Tropical Belt*, 4 and 5 are the *North Tropical Belt*, 6 is the *North Temperate Band*, and 7 the *Northern North Temperate Band.* The central coloured zone is the *Equatorial Zone.*

I.

Description of the Dark Bands, Spots, and Bright Zones.

Band 0.

1899 April 12, $10\frac{1}{2}^h$ (the longitude of the central meridian $=29°$); a faint narrow band, very little to the south of dark band 1. April 17, 10^h (43°), as on April 12, except that 1 being now narrower than on the 12th, the bright space between 0 and 1 is wider. April 30, 10^h (198°); a faint narrow band bounding the S. polar shading. May 3, 10^h (289°); well seen as on April 30. Bright zone 0 to 1 is wide. May 4, 10^h (79°) and 11^h (116°); as on May 3. May 5, 9^h(194°); faint; at 10^h (230°) the band disappears on the central meridian, *i.e.* it is not seen on the eastern half of the disc when the longitude of the central meridian is about 233°. At this time the eastern half of 1 is broad. May 6, $8\frac{1}{2}^h$ (326°); nearly as broad as 1; at 10^h (20°) broader than 1. May 7, $8\frac{1}{2}^h$ (116°); as wide and dark as 1; at 9^h 40^m (89°) faint. May 16, $10\frac{1}{2}^h$ (102°); seen all across the disc. May 17, 9^h 17^m (208°); the band ceases just a little to the east of where 1 begins to be broader and darker; the end was on the central meridian about 9^h $52\frac{1}{2}^m$ (230°). May 26, 9^h (111°); seen all across the disc. May 27, 8^h 45^m (252°); a short portion of the band seen near the *f* limb. May 30, 9^h (352°); as on May 26 at 9^h.

Summary.—This was a narrow but easily seen grey band usually; faint in some longitudes, absent in others; as broad or broader than 1 in some longitudes; suddenly disappeared when the longitude of the central meridian was about 230°.

Band 1 (*South Temperate Band*).

1899 January 16, 19^h (7°); faint. The "shoulders" are now about central; the band has a darker portion just over the *f* shoulder. January 23, 19^h (339°); a strap-like band; it is wider and darker over the Red Spot. April 16, 11^h 19^m (300°); the *p* shoulder is near the *f* limb; the band is strap-like. April 30, 10^h (198°); a narrow and rather faint band. At 11^h (234°) it seemed wider and darker near the *f* limb. May 3, 8^h (217°); broader at the *f* end than elsewhere; at $10\frac{1}{4}^h$ (298°) broader

than at 8^h or 9^h; at 11^h (325°) as at $10\frac{1}{4}^h$. May 4, 9^h (43°); broader and darker over the Red Spot. May 5, 9^h (194°); darker and broader near the *f* limb than elsewhere; at 10^h (230°) the broader part is from the middle to the *f* limb; at 11^h 20^m (278°) as broad as 2 or 3. May 6, $8\frac{1}{2}^h$ (326°); a broad band; at 10^h the band seemed to curve up to the south over the great hollow between the two shoulders. May 7, 8^h (98°); narrow; at 11^h (207°) the eastern half is broader and darker than the western. May 15, $9\frac{1}{2}^h$ (275°); broader than 2 or 3 or 4, but not nearly so dark; strap-like. May 16, $8\frac{1}{2}^h$ (30°); not broad; not so dark as band 6. May 17, 9^h (198°); narrow and faint, and variable in width and darkness; at 9^h 17^m (208°) it begins to broaden and darken; at 10^h and 11^h (234° and 270°) a broad and conspicuous band. May 25, 8^h (284°); broad all the way across the disc. May 26, 9^h (111°); not broad; rather faint. A gap in it and a dusky spot on it near the central meridian at 11^h (183°); wider near the *f* limb. May 27, $8\frac{1}{2}^h$ (243°); broad all the way across the disc; at 10^h 20^m (310°) a wider part on the central meridian extending to *f* limb. May 28, 9^h (52°) faint all across the disc. May 31, 8^h (106°) and 9^h (143°); faint; at 10^h wider near the *f* limb. June 1, 9^h (293°); faint. June 2, 10^h (119°); faint; a broader part near the *f* limb. June 3, 10^h (270°); a broad, strap-like band. June 15, $9\frac{1}{4}^h$ (246°); a broader part near the *f* limb.

Summary.—In general a grey, strap-like band; varies considerably in breadth and depth of tone in certain longitudes. In some parts it is sinuous, and consists of a succession of light and dark portions; at least one break in it and one cloudy spot on it.

Band 2 and the Double Band 2.3.

January 16, 19^h (7°). The Red Spot, the two shoulders, and the hollow between them seem very little, if at all, changed since the last opposition. During the present opposition band 2 has presented no special features calling for remark. Band 2 is now seen much less dark than 3 all the way from the *p* shoulder to the *p* limb. April 12, $10\frac{1}{2}^h$ (29°); 2 and 3 well separated. April 16, 12^h (325°); as on April 12; 2 not so dark as 3. April 17, 10^h (43°); 2 and 3 separated by a fine bright line; so also on April 30 at 10^h (198°). May 3, 8^h (217°); 2 and 3 together darker than 4.5. May 4, 10^h (79°); 2 and 3 very close, and as broad as 4.5; at 11^h (116°) equally dark and darker than 4.5. May 5, 8^h (157°); 2 as dark as 3; at 11^h 20^m (278°) 2 and 3 not dark. May 7, 8^h (98°); 2.3 much darker than 4.5, and narrower; at 11^h (207°) 2.3 and 4.5 much alike in depth of tone and breadth. May 15, $9\frac{1}{2}^h$ (275°); 2.3 as broad as 4.5, and no darker than 4.5. May 16, $10\frac{1}{2}^h$ (102°); 2.3 the darkest feature of the disc; as broad as 4.5. May 25, 8^h (284°); 2.3 and 4.5

equally broad and dark. May 31, 8^{h} (106°); 2.3 much darker than 4.5. June 14, 9^{h} (86°); 2.3 a dark ruddy colour.

Summary.—Band 2 was almost featureless. An hour or two before the Red Spot reaches the central meridian this band becomes paler and narrower, and the bright space between 2 and 3 wider. This local weakening of band 2 is noteworthy, as it seems permanent. It has been noticed here for several years. It is unbroken, except where it bends down to 3 and disappears between the two shoulders. Band 3 has been one of the best marked features during this and several preceding oppositions. Its most noteworthy features were a considerable number of dark spots on its northern edge, short breaks or bright gaps, and its uniformly dark tint in all longitudes. In some presentations of the disc as many as six long dark spots could be seen at one time. Some lay on the N. edge of the band, in contact with it, and also projecting into the coloured central zone; others were probably short portions of the band itself, separated from each other by bright spaces of about the same length. It was easy to think of these dark pieces of band and bright separating spaces as forming a row of festoons from limb to limb. There was a dark spot on 3 about in the longitude of the slope of the *p* shoulder; another in that of the middle of the great hollow. In the case of the dark spot which was on the central meridian about $11^{h}\ 20^{m}$ May 5 we have an example of the detachment of a short portion of the belt from the rest with a narrow bright space at each end. The dark portion had lost its parallelism to the general direction of the belt, its *p* end being more N. than the *f* end. When the dark spots lay on the N. edge of the band the latter was sometimes seen much narrower and fainter than elsewhere. And these spots stood out with greater distinctness owing to the presence of a narrow bright space along the northern edge of the band—a space free from yellow colour, and much brighter than the coloured zone (central) in which it lay. At $9^{h}\ 12^{m}$ June 6 the band seemed cut up into lengths separated by bright spaces. The lengths varied from 2″ or 3″ to several seconds of arc. The dark spot just under the *p* shoulder seemed on June 16 to have a fainter portion stretching away to the N.E., and thus connecting it with the faint narrow band which lay along the middle of the coloured zone.

Bands 4.5.

This broad, double, dark band has changed much since the opposition of 1897–8. April 17, 10^{h}; three dark spots lay on band 5 and one on band 4, to the east of the central meridian. April 30, 10^{h}; a little west of the central meridian there was a break or gap in 4 and a dark spot on 5; while to the east of that meridian 5 was quite a faint band. May 3, $10\frac{1}{4}^{h}$; the *f* half of 5 was a faint, inconspicuous band, while 4 remained dark and

broad; at 11^h, to the east of the central meridian, 4 had a curved portion extending into the coloured central zone; at 11^h 10^m there was a bright gap or break in 5 to the east of the central meridian. May 6, $8\frac{1}{2}^h$; bands 4.5 were diffuse; 4 was darker than 5 and more continuous. At 10^h a straight portion of 4 was seen near the *f* limb, while the rest of the two bands was lighter, diffuse, and contained bright gaps and dark grey portions. May 7, 10^h; there were breaks or gaps in both bands, and a dark spot on the N edge of 5. May 5, 8^h; the bands were diffuse and full of gaps. May 16, $10\frac{1}{2}^h$; two very conspicuous bright gaps in band 5 were seen. May 17, 9^h; band 5 was very faint to the east of the central meridian, and at 11^h three bright gaps were seen in it. May 30, 10^h; a bright gap in 5 and a dark spot over it in band 4 were well seen.

Summary.—The principal features of this broad double band (4.5) were diffuseness along the N. edge of 4, sharpness of the S. edge of 5, dark spots on 5 or its separation into dark pieces, bright gaps in band 5, variable width and the frequent curvature of portions of 4. In some places a narrow, dark piece of 4 seemed to lie on a light grey ground. The two bands were in most longitudes separated by a narrow bright streak; the two together were never less broad than 3.4, were often broader, often less dark than they, and sometimes quite as dark.

Bands 6 *and* 7.

May 7, 9^h, band 6 was faint. May 15, $9\frac{1}{2}^h$, it was invisible to the east of the central meridian; 7 was darker than 6, and darker than 1. May 17, 9^h, bands 6 and 7 were close, narrow, but well seen. May 23, 11^h, both well seen. May 30, 9^h, band 7 was faint; 6 not so broad as 1, but darker; at 10^h 6 was much fainter than 7. June 3, 10^h, 6 and 7 close, narrow, darker than 1. June 16, 10^h, 6 was a delicate, narrow, and rather faint band; 7 much darker and broader than 6.

Summary.—These bands were usually far from being conspicuous; in certain longitudes, however, they were very marked features. They were not continuous all round the planet.

The Red Spot.

The region (between the two shoulders) in which this remarkable object lies was carefully examined on more than twenty nights. Portions of its outline were glimpsed occasionally on several nights; but it was not well seen till June 16, between 8^h and 9^h; and the portion best seen was the S. half of the curve. The centre of the spot seemed to be in about the same latitude as the south edge of the great *f* shoulder, and its longitude was a little behind that of the middle of the hollow; in other words, the ellipse seemed to be not quite symmetrically placed with reference to the shoulders and the hollow between

them. Neither colour nor shading of any kind was seen within the ellipse; nor did the space between the two shoulders in which the Red Spot lies ever appear brighter than the bright zone to the east or west of it. The following end of the spot was often glimpsed.

The Bright Zones.

On all occasions it was noted that the parts of the disc to the S. of band 2 were much brighter than those to the N. of band 5, and the zone between 1 and 2 was the brightest of all. The great central coloured zone between 3 and 4 was, of course, always a most striking feature: its colour was a warm yellow. Here, too, may be mentioned a narrow, bright, colourless zone close to dark band 3 on its N. edge, and a similar one on the S. edge of dark band 4: both were parts of the great central zone. It was in these two narrow bright zones that the dark spots under 3 and on 4 lay.

The Narrow Equatorial Band.

Between dark bands 3 and 4, but nearer to 4 than to 3, a narrow band was nearly always seen. On nights of bad definition it seemed to merge into bands 4.5, and with them to form a very broad dark zone across the disc.

Dark and Bright Spots.

Some remarks have already been made on the dark spots seen on the dark bands, or projecting from their edges. Not one, perhaps, was seen quite detached from a dark band, and lying isolated in a bright zone. It is just possible, however, that a dark spot seen to the west of the central meridian at 9^h, May 5, was really not in contact with band 5, but lay in the bright zone between 5 and 6: its length was a little more than $1''$, and it was noted that directly above it (to the south) a gap of corresponding size existed in the dark band 5, just as if a short piece of the dark band had become detached and moved a little northwards into the bright zone between 5 and 6.

Two large diffuse grey spots were seen on band 0 at $9^h\ 20^m$, May 5.

A dusky spot was seen on band 1 at 11^h, May 26; it was on the band, but also extended into the bright zone between bands 0 and 1. Close to it, to the east, the dark band had a gap in it, as if the spot had been drawn from the band, and moved a little south and west.

There were very few dark spots on band 4, the most noteworthy one being that which was on the central meridian about 11^h, May 30. Here, again, a gap in band 5 was seen just under (to N. of) the dark spot on 4.

II.

Transits of Dark Spots.

On Dark Band 3.

	1899.	h m	°
a	Jan. 16	18 50	1
	May 3	12 5	5
	6	9 35	5
b	May 3	10 13	297
	15	10 5	297
	27	10 0	298
c	May 7	9 47	163
d	May 3	11 20	337
	6	8 53	341
e	Jan. 24	19 21	352
f	May 7	8 43	124
	26	9 15	120
g	Apr. 17	10 30	61
h	May 5	11 20	278
	15	9 27	276
	17	11 15	280
i	Apr. 17	11 5	82
j	May 5	9 5	197
k	May 17	8 46	190
	26	11 8	188
	31	10 18	190
l	May 17	9 45	225
	June 3	8 49	227
m	May 31	9 45	170
	June 17	8 47	169
n	May 17	10 33	254
	27	8 42	251
o	May 26	9 5	114
p	May 25	10 42	22
q	May 27	10 46	325
r	May 31	9 7	147
s	June 2	9 25	98
t	June 3	9 13	241
	July 26	8 15	247
u	June 3	10 0	270
	July 26	8 45	265
v	June 15	8 28	217
w	June 16	9 37	49
x	June 16	8 50	15

On Dark Band 4.

	1899.	h m	°
a	Apr. 17	11 10	85
b	May 30	11 0	65

On Dark Band 5.

	1899.	h m	°
a	Jan. 24	19 30	357
b	Apr. 17	10 0	43
c	May 7	10 3	173
d	May 31	9 28	160

On Dark Band 1.

1899.	h m	°
May 26	11 0	184

Transits of Bright Spots.

On Dark Band 5.

	1899.	h m	°		1899.	h m	°
a	May 28	9 20	64	*c*	May 27	10 45	325
	30	11 0	65		June 6	8 55	321
	June 6	11 40	61				
	11	10 48	61	*d*	May 16	10 40	108
	14	8 20	59		23	11 20	105
	16	9 55	60	*e*	May 23	10 30	75
b	July 26	8 55	271	*f*	May 3	11 10	331

On Dark Band 3.

1899.	h m	°	1899.	h m	°
May 27	8 57	259	June 15	9 32	256

The Red Spot.

As this object was but seldom seen, the transit of the middle of the great hollow was observed, this point and the centre of the Red Spot being very nearly in the same longitude.

1899.	h m	°		h m	°
April 12	10 36	32	June 4	9 17	34
16	13 52	32	6	10 56	34
17	9 41	31	9	8 25	34
26	12 3	31	11	10 3	34
May 4	8 44	31	14	7 32	33
6	10 20	32	16	9 12	34
8	11 57	32	21	8 20	34
16	8 34	32	26	7 28	34
18	10 14	33	July 5	9 56	35
25	11 0	33	15	8 15	35
28	8 30	33	27	8 10	34
30	10 8	33			

The p *Shoulder.*

This feature not being a well-defined point was not easy to observe very consistently, as the following discordant results will show :—

1899.	h m	°		h m	°
May 6	9 50	14	June 6	10 20	13
16	8 13	19	11	9 35	17
25	10 32	16	16	8 40	15
30	9 37	15	July 5	9 27	17

The f Shoulder.

	h m	°		h m	°
April 17	10 15	52	June 6	11 25	51
May 4	9 17	54	9	8 55	52
16	9 10	54	11	10 30	50
18	10 42	50	16	9 43	53
28	9 0	52	July 5	10 25	52
30	10 41	53	15	8 42	52

The longitudes of the central meridian have not been corrected for phase.

III.

Measures.

Latitudes and Widths of Bands.

Dark Band 1 (*latitude*). (*The S. Temperate Band.*)

1899.	"	°	1899.	"	°
Apr. 30	−7·8	198	June 15	−8·1	219
May 5	−7·3	176	16	−7·5	9
30	−8·1	334	17	−7·8	141
June 13	−7·5	260	July 14	−8·0	236
14	−7·7	86	16	−8·2	194

The third column gives the longitude of the central meridian at the time of observation.

Mean −7″·8.

Middle of the Double Dark Band 2.3 (*latitude*). (*The S. Tropical Belt.*)

1899.	"	°	1899.	"	°
Apr. 17	−2·8	43	May 26	−2·6	111
22	−3·1	111	30	−3·1	316
30	−3·6	198	June 14	−3·3	68
May 4	−2·4	79	15	−3·2	219
5	−3·4	175	17	−3·0	159
16	−2·9	120	July 16	−2·7	194

Mean −3″·0.

Middle of the Double Dark Band 4.5 (*latitude*). (*The N. Tropical Belt.*)

1899. Apr. 22	+4″·6	111°	1899. May 30	+4″·5	316°
May 5	+4·8	175	June 14	+4·6	68
16	+4·7	120	17	+4·4	141
26	+4·7	111	July 16	+5·1	194

Mean +4″·7.

South Edge of Dark Band 2 (*latitude*).

1899. Apr. 17	−4″·1	43°	1899. June 14	−4″·2	68°
May 5	−4·7	175	15	−4·6	219
26	−4·4	111	17	−5·2	141
June 13	−3·6	260	July 16	−4·7	194

Mean −4″·4.

North Edge of Dark Band 5 (*latitude*).

1899. Apr. 17	+6″·4	43°	1899. May 26	+6″·1	111°
May 5	+6·1	175	July 16	+6·4	194

Mean +6″·2.

Middle of the Central (coloured) Zone (latitude).

1899. May 5	+0″·8	175°	1899. June 14	+0″·9	68°
26	+1·3	111	17	+0·6	141
June 13	+1·0	260	July 14	+0·8	236

Mean +0″·9.

S. Edge of the N. Polar Shading (*latitude*).

1899. June 13	+ 9″·2	260°	1899. June 16	+12″·4	9°
14	+11·5	68	17	+11·4	141
15	+ 9·2	219			

Mean +10″·7.

N. Edge of the S. Polar Shading (*latitude*).

1899. June 14	−10″·1	68°	1899. June 16	− 9″·2	9°
15	− 9·2	219	17	− 9·6	141

Mean −9″·5.

Dark Band 6 (*latitude*). (*The N. Temperate Band.*)

1899. June 14	+ 8″·5	86°	1899. July 16	+ 10″·0	194°

Mean + 9″·2.

Width of Dark Band 1. (*The S. Temperate Band.*)

1899. June 14	1″·1	86°

Width of the Dark Bands 2.3. (*The S. Tropical Belt.*)

1899. April 17	2″·9	52°	1899. May 30	3″·5	334°
„ 22	3·3	111	June 13	3·1	260
„ 30	2·7	198	„ 14	2·8	68
May 4	3·4	79	„ 15	3·3	219
„ 5	3·2	175	„ 17	3·1	159
„ 16	3·4	120	July 14	2·9	236
„ 26	3·5	111	„ 14	2·9	272
„ 28	3·5	33	„ 16	2·7	194

Mean, 3″·1.

Width of the Dark Bands 4.5. (*The N. Tropical Belt.*)

1899. April 17	4″·9	52°	1899. May 30	3″·5	334°
„ 22	4·7	111	June 13	3·1	260
May 4	3·4	79	„ 14	3·5	68
„ 5	3·2	175	„ 17	3·7	159
„ 16	3·4	120	July 14	2·9	236
„ 26	3·5	111	„ 14	2·9	272
„ 28	3·8	33	„ 16	2·7	194

Mean, 3″·5.

Width of Bands 2.3, *the Central Zone, and Bands* 4.5.

1899. April 17	10″·8	43°	1899. June 13	9″·2	260°
„ 30	9·9	198	„ 14	11·0	86
May 4	10·6	79	„ 15	9·2	219
„ 5	11·4	176	„ 16	10·6	9
„ 16	11·0	120	„ 16	11·1	53
„ 16	10·8	120	„ 17	10·8	141
„ 26	11·8	111	July 14	9·3	236
„ 28	11·6	33	„ 14	9·1	272
„ 30	11·6	316	„ 16	9·2	194

Mean, 10″·5.

Width of the Central Coloured Zone.

a. Direct Measures.

1899.	″	°	1899.	″	°
April 17	2·9	43	June 14	3·6	86
May 5	3·7	176	„ 17	3·7	141
„ 16	4·0	120	July 14	3·7	236
„ 26	4·7	111	„ 14	3·4	272
„ 28	4·1	33	„ 16	4·3	194
June 13	3·6	260			

Mean, 3″·8.

b. Width deduced from Measures of 2·3, 4·5, and 2 to 5.

3″·0, 3″·8, 5″·0, 4″·2, 4″·8, 4″·3, 4″·6, 3″·0, 4″·7, 4″·0.

Mean, 4″·1.

Note.—Band 5 extends more to the N. in some longitudes than in others.

Width of the Bright Zone 1 *to* 2.

1899.	″	°	1899.	″	°
April 17	2·0	43	June 16	1·2	9
June 14	1·8	86	July 14	1·9	236

Mean, 1″·7.

Width of the Bright Zone 5 *to* 6.7.

1899.	″	°	1899.	″	°
June 14	1·6	86	July 14	2·7	272
„ 16	2·5	9			

Mean, 2″·3.

Note.—The width of this zone depends on the presence or absence of band 6.

The above measures are reduced to mean distance 5·20, but are not corrected for the latitude of the Earth above *Jupiter's* equator.

Latitudes and Widths of Bands from 1895–96 to 1898–99.

The S. Temperate Band (1).

	″			″	
1895–6	−8·7	10 nights	1897–8	−7·8	17 nights
6–7	−8·2	10 „	8–9	−7·8	10 „

The S. Tropical Belt (2,3).

	″			″	
1895–6	−3·9	20 nights	1897–8	−3·5	6 nights
6–7	−3·4	23 „	8–9	−3·0	11 „

The N. Tropical Belt (4·5).

1895–6	+2″·4	30 nights (single and narrow)
6–7	+4·1	16 „ (double)
7–8	+3·6	18 „ (single)
8–9	+3·0	14 „ (double)

The N. Temperate Band (6).

1895–6	+7″·4		1898–9	+9″·2	2 nights
7–8	+7·0	5 nights			

The Middle of the Coloured Central Zone.

1896–7	+0″·3	4 nights	1898–99	+0″·7	9 nights
7–8	+0·6	8 „			

The S. Edge of Band 2.

1895–6	−5″·7	20 nights	1898–9	−4″·4	8 nights

N. Edge of Band 5.

1895–6	+2″·4	30 nights (single and narrow)
6–7	+6·0	17 „ (double)
8–9	+6·2	4 „ (double)

This band was single in 1897–98.

Width of the Dark Band 1.

1896–7	1″·1	5 nights	1898–9	1″·1	1 night
7–8	1·4	2 nights			

Width of the Equatorial Coloured Zone.

(Between dark bands 3 and 4.)

1895–6	3″·6	15 nights	1897–8	3″·6	11 nights
6–7	3·0	16 „	8–9	3·8	11 „

Width of the S. Tropical Zone.

(Between bands 1 and 2.)

1896–7	1″·7	5 nights	1898–9	1″·7	4 nights
7–8	1·4	5 „			

Width of 2.3, the Central Coloured Zone, and 4.5.

1895–6	7″·9	20 nights	1897–8	8″·3	16 nights
6–7	10·9	23 „	8–9	10·5	18 „

Width of the Band 2.3.

1895–6	3″·3	30 nights	1897–8	3″·5	14 nights
6–7	3·8	20 „	8–9	3·1	16 „

Width of the Band 4.5.

1895–6	about 1″·0		Very narrow : single.
6–7	3·9	17 nights	(double)
7–8	1·3	11 „	(single)
8–9	3·5	14 „	(double)

Width of the Band 1. (S. Temperate Band.)

1896–7	1″·1		1898–9	1″·1	1 night
7–8	1·4	2 nights			

IV.

Notes on the Satellites and their Shadows.

1889 May 6. II. transit I.—Ingress about $9^h\ 42^m$; it was much brighter than the limb, but grew gradually fainter, and was but just visible when in mid-transit. It moved along a narrow bright zone between two grey bands a good way N. of the equator.

1899 May 7. I. transit I. Satellite much brighter than the limb ; grew fainter as it advanced ; was very faint at $9^h\ 25^m$; invisible at $9^h\ 35^m$. It moved along a bright zone.

1899 May 30. I. transit I. Ingress about $8^h\ 51^m$; invisible at $9\frac{1}{2}^h$ and 10^h. It moved along the N. edge of the N. equatorial dark belt, and was again visible at $10^h\ 40^m$. It did not appear dusky or dark at any time during transit. The shadow's ingress took place about $9^h\ 37^m$. It often seemed elongated in a direction parallel to the equator during the first hour of transit ; when central it was circular. At and after central transit it seemed smaller than before transit. The same remarks apply to the transit of the shadow of I. on June 6.

On June 15 the shadow of I. was watched during the first half of its transit ; no changes of shape were seen : central about $8^h\ 50^m$.

On July 15 I. was observed at ingress : it moved along a dark band, and became invisible 20^m after ingress at $8^h\ 50^m$.

V.

Phenomena of Jupiter's Satellites.

Day of Obs. 1899.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	G.M.T. of *N. Almanac.* h m s
May 6	II.	Tr. I.	External contact	9 43	9 42 0
			Bisection	9 45	
			Internal contact	9 46	
	II.	Sh. I. (*a*)	Internal contact	10 14	10 11 0
7	I.	Tr. I. (*b*)	External contact	9 7	9 7 0
			Bisection	9 8	
			Internal contact	9 9 30	
	I.	Sh. I.	Internal contact	9 27	9 24 0
	I.	Tr. E.	Internal contact	11 14	11 18 0
			Bisection	11 15 30	
			External contact	11 17	
30	I.	Tr. I. (*c*)	External contact	8 50 30	8 51 0
			Internal contact	8 55	
	I.	Sh. I.	Internal contact	9 37	9 37 0
	I.	Tr. E.	Internal contact	10 59	11 3 0
			External contact	11 2 30	
31	III.	Ec. D. (*d*)	Last seen	8 32 16	8 32 36
	I.	Ec. R.	First seen	9 0 44	9 0 55
			Full ?	9 2	
	II.	Sh. E.	Internal contact	9 25 0	9 30 0
	III.	Ec. R.	First seen	10 2 41	10 2 55
			Bisection ?	10 5	
			Full ?	10 10	
June 6	I.	Tr. I. (*e*)	External contact	10 39 30	10 39 0
			Internal contact	10 42 30	
14	I.	Oc. D.	External contact	9 39 30	9 39 0
			Just gone	9 41 30	
	I.	Tr. E.	Internal contact	9 3	9 7 0
15	I.	Sh. E. (*f*)	Internal contact	10 5	10 8 0
			Bisection	9 4 30	
			External contact	9 6	
July 15	I.	Tr. I. (*g*)	External contact	8 49 30	8 50 0
			Bisection	8 51	
			Internal contact	8 52	
16	II.	Tr. I. (*h*)	External contact	9 25 30	9 19 0

Notes.

(*a*) Much boiling on limb. (*b*) Bad definition to-night. (*c*) Very bad definition. (*d*) Very much motion to-night. (*e*) Planet very low; bad definition. (*f*) Much boiling on limb of planet. (*g*) As on June 15. (*h*) Violent motion.

Ephemeris for Physical Observations of

Greenwich Noon.		P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1899.		°	°	°	′	′	″	°	°	°
Dec.	17	13.15	102.726	−2.947	32.08	0.06	30.06	4.78	284.33	−3.14
	19	12.98	103.143	2.948	32.16	0.06	30.14	5.04	284.10	3.15
	21	12.81	103.557	2.950	32.25	0.07	30.22	5.30	283.88	3.15
	23	12.65	103.967	2.952	32.34	0.08	30.31	5.56	283.66	3.15
	25	12.48	104.375	2.953	32.43	0.08	30.39	5.81	283.45	3.15
	27	12.32	104.777	−2.955	32.53	0.09	30.49	6.06	283.24	−3.15
	29	12.16	105.176	2.957	32.63	0.10	30.58	6.30	283.03	3.15
	31	12.00	105.571	2.959	32.74	0.11	30.69	6.54	282.82	3.16
1900. Jan.	2	11.84	105.961	2.960	32.85	0.11	30.79	6.77	282.62	3.16
	4	11.69	106.348	2.962	32.97	0.12	30.91	7.00	282.42	3.16
	6	11.54	106.728	−2.964	33.09	0.13	31.02	7.23	282.23	−3.16
	8	11.38	107.103	2.966	33.21	0.14	31.13	7.45	282.04	3.16
	10	11.23	107.473	2.968	33.34	0.15	31.25	7.66	281.86	3.17
	12	11.09	107.838	2.969	33.48	0.16	31.38	7.87	281.78	3.17
	14	10.94	108.196	2.971	33.62	0.16	31.51	8.08	281.51	3.17
	16	10.80	108.550	−2.973	33.77	0.17	31.65	8.28	281.35	−3.17
	18	10.65	108.896	2.975	33.92	0.18	31.79	8.47	281.18	3.17
	20	10.51	109.237	2.976	34.07	0.19	31.93	8.65	281.01	3.17
	22	10.37	109.570	2.978	34.23	0.20	32.08	8.83	280.85	3.18
	24	10.23	109.898	2.979	34.39	0.21	32.23	9.00	280.69	3.18
	26	10.10	110.217	−2.981	34.56	0.22	32.39	9.16	280.53	−3.18
	28	9.97	110.530	2.982	34.73	0.23	32.55	9.32	280.38	3.18
	30	9.84	110.835	2.984	34.91	0.24	32.72	9.47	280.23	3.18
Feb.	1	9.71	111.132	2.985	35.09	0.25	32.88	9.61	280.09	3.18
	3	9.59	111.421	2.987	35.28	0.26	33.06	9.74	279.95	3.19
	5	9.48	111.702	−2.988	35.47	0.27	33.24	9.87	279.82	−3.19
	7	9.35	111.973	2.990	35.66	0.27	33.42	9.98	279.69	3.19
	9	9.24	112.238	2.992	35.86	0.28	33.61	10.09	279.56	3.19
	11	9.13	112.492	2.994	36.06	0.29	33.79	10.19	279.44	3.19
	13	9.03	112.738	2.996	36.26	0.29	33.98	10.28	279.32	3.20
	15	8.93	112.973	−2.999	36.47	0.30	34.18	10.36	279.20	−3.20
	17	8.83	113.199	3.001	36.68	0.30	34.38	10.43	279.09	3.20
	19	8.74	113.416	3.003	36.90	0.31	34.59	10.49	278.98	−3.20
	21	8.65	113.623	3.005	37.12	0.31	34.79	10.54	278.87	3.21
	23	8.57	113.819	−3.007	37.34	0.32	35.00	10.58	278.77	−3.21

Jupiter, 1899–1900. By A. C. D. Crommelin.

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I	870°·27 II.	Corr. for Phase.	Light-time.	A − O.	*B.*
1899.	°	°	°	m	°	°
Dec. 17	186·01	315·10	+0·11	51·929	97·939	−3·038
19	141·47	255·29	0·12	51·798	98·094	3·037
21	96·94	195·49	0·14	51·661	98·249	3·036
23	52·42	135·71	0·15	51·520	98·404	3·035
25	7·90	75·94	0·16	51·369	98·559	3·034
27	323·39	16·18	+0·17	51·210	98·715	−3·033
29	278·89	316·43	0·18	51·049	98·870	3·031
31	234·40	256·68	0·19	50·881	98·025	3·030
1900. Jan. 2	189·91	196·93	0·21	50·706	98·180	3·029
4	145·43	137·19	0·22	50·525	99·335	3·027
6	100·97	77·46	+0·23	50·337	99·490	−3·026
8	56·52	17·74	0·24	50·146	99·645	3·024
10	12·07	318·03	0·26	49·950	99·800	3·023
12	327·62	258·33	0·27	49·747	99·955	3·022
14	283·19	198·64	0·29	49·539	100·110	3·020
16	238·77	138·95	+0·30	49·326	100·265	−3·019
18	194·36	79·28	0·31	49·109	100·421	3·017
20	149·95	19·62	0·33	48·888	100·576	3·016
22	105·56	319·97	0·34	48·661	100·732	3·014
24	61·18	260·32	0·36	48·430	100·887	3·013
26	16·79	200·67	+0·37	48·195	101·043	−3·011
28	332·42	141·04	0·38	47·957	101·198	3·010
30	288·06	81·42	0·39	47·715	101·354	3·008
Feb. 1	243·71	21·81	0·40	47·469	101·509	3·006
3	199·37	322·21	0·41	47·220	101·665	3·004
5	155·05	262·63	+0·42	46·968	101·821	−3·003
7	110·74	203·06	0·43	46·713	101·977	3·001
9	66·44	143·50	0·44	46·456	102·133	2·999
11	22·14	83·94	0·45	46·196	102·288	2·997
13	337·85	24·39	0·46	45·934	102·444	2·995
15	293·57	324·84	+0·47	45·670	102·600	−2·994
17	249·30	265·31	0·47	45·405	102·756	2·992
19	205·05	205·79	0·48	45·138	102·911	2·990
21	160·81	146·29	0·48	44·869	103·067	2·988
23	116·58	86·80	+0·49	44·600	103·223	−2·986

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a	Defect.	Polar 2b.	d.	Q.	B′.
1900.	°	°	°	″	″	″	°	°	°
Feb. 25	8.49	114.005	−3.009	37.57	0.32	35.22	10.61	278.66	−3.21
27	8.41	114.180	3.011	37.80	0.32	35.43	10.63	278.56	3.21
Mar. 1	8.34	114.344	3.013	38.04	0.33	35.65	10.64	278.46	3.21
3	8.28	114.497	3.016	38.28	0.33	35.87	10.64	278.37	3.22
5	8.22	114.639	3.018	38.52	0.33	36.10	10.62	278.28	3.22
7	8.16	114.768	−3.020	38.76	0.33	36.32	10.59	278.20	−3.22
9	8.11	114.887	3.023	39.00	0.33	36.55	10.56	278.12	3.22
11	8.06	114.993	3.025	39.24	0.33	36.78	10.51	278.05	3.23
13	8.02	115.089	3.028	39.49	0.33	37.01	10.45	277.98	3.23
15	7.98	115.171	3.030	39.74	0.32	37.25	10.37	277.92	3.23
17	7.95	115.242	−3.032	39.99	0.32	37.48	10.29	277.86	−3.23
19	7.92	115.301	3.034	40.24	0.32	37.72	10.19	277.81	3.24
21	7.90	115.347	3.036	40.49	0.31	37.95	10.08	277.76	3.24
23	7.89	115.380	3.039	40.74	0.31	38.19	9.96	277.72	3.24
25	7.88	115.402	3.041	40.99	0.30	38.42	9.83	277.68	3.24
27	7.88	115.411	−3.043	41.24	0.30	38.66	9.68	277.64	−3.25
29	7.88	115.407	3.045	41.49	0.29	38.89	9.52	277.60	3.25
31	7.89	115.390	3.047	41.74	0.28	39.12	9.34	277.57	3.25
April 2	7.90	115.361	3.049	41.98	0.27	39.35	9.16	277.53	3.25
4	7.92	115.319	3.051	42.23	0.26	39.58	8.96	277.50	3.25
6	7.94	115.265	−3.053	42.47	0.25	39.81	8.75	277.47	−3.26
8	7.97	115.198	3.055	42.71	0.24	40.04	8.53	277.44	3.26
10	8.01	115.120	3.057	42.94	0.23	40.25	8.29	277.41	3.26
12	8.05	115.030	3.058	43.17	0.22	40.47	8.05	277.39	3.26
14	8.09	114.928	3.060	43.40	0.21	40.68	7.79	277.36	3.26
16	8.14	114.815	−3.061	43.62	0.19	40.89	7.52	277.34	−3.27
18	8.20	114.689	3.062	43.84	0.18	41.10	7.24	277.31	3.27
20	8.25	114.553	3.063	44.05	0.16	41.29	6.95	277.29	3.27
22	8.32	114.406	3.065	44.25	0.15	41.47	6.64	277.26	3.27
24	8.38	114.249	3.066	44.44	0.13	41.65	6.33	277.24	3.27
26	8.45	114.081	−3.067	44.63	0.12	41.83	6.00	277.21	−3.27
28	8.53	113.904	3.067	44.81	0.11	42.00	5.67	277.16	3.27
30	8.61	113.716	3.068	44.98	0.10	42.16	5.33	277.09	3.27
May 2	8.70	113.521	3.068	45.15	0.09	42.32	4.98	277.01	3.27
4	8.79	113.317	3.068	45.30	0.08	42.46	4.62	276.92	3.27
6	8.88	113.107	−3.068	45.44	0.06	42.59	4.25	276.82	−3.27
8	8.97	112.887	3.068	45.57	0.05	42.71	3.87	276.65	3.27
10	9.07	112.662	−3.067	45.69	0.04	42.82	3.49	276.43	−3.27

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A – O.	*B*.
1900.	°	°	°	m	°	°
Feb. 25	72·36	27·32	+0·49	44·330	103·379	–2·984
27	28·15	327·85	0·49	44·060	103·535	2·982
Mar. 1	343·95	268·39	0·49	43·790	103·691	2·980
3	299·76	208·94	0·49	43·519	103·847	2·978
5	255·58	149·50	0·49	43·249	104·003	2·976
7	211·42	90·07	+0·49	42·979	104·160	–2·974
9	167·27	30·65	0·48	42·711	104·316	2·972
11	123·13	331·24	0·48	42·445	104·472	2·970
13	79·00	271·85	0·47	42·177	104·628	2·968
15	34·88	212·47	0·47	41·913	104·784	2·966
17	350·76	153·10	+0·46	41·652	104·940	–2·964
19	306·65	93·74	0·45	41·393	105·096	2·961
21	262·56	34·39	0·44	41·137	105·253	2·959
23	218·48	335·05	0·43	40·883	105·409	2·957
25	174·42	275·72	0·42	40·633	105·565	2·955
27	130·36	216·39	+0·41	40·386	105·722	–2·953
29	86·31	157·09	0·40	40·143	105·879	2·950
31	42·27	97·80	0·38	39·904	106·035	2·948
April 2	358·24	38·51	0·36	39·669	106·192	2·946
4	314·22	339·23	0·35	39·440	106·349	2·944
6	270·22	279·95	+0·33	39·217	106·505	–2·941
8	226·23	220·69	0·31	38·999	106·662	2·939
10	182·24	161·43	0·30	38·786	106·818	2·936
12	138·25	102·18	0·28	38·578	106·975	2·934
14	94·27	42·94	0·26	38·377	107·131	2·931
16	50·30	343·72	+0·25	38·183	107·288	–2·929
18	6·34	284·50	0·23	37·996	107·444	2·926
20	322·38	225·28	0·22	37·816	107·601	2·924
22	278·43	166·07	0·20	37·642	107·758	2·921
24	234·49	106·87	0·18	37·477	107·915	2·919
26	190·56	47·68	+0·16	37·320	108·072	–2·916
28	146·63	348·48	0·14	37·171	108·229	2·914
30	102·70	289·29	0·13	37·030	108·386	2·911
May 2	58·78	230·10	0·12	36·897	108·543	2·908
4	14·86	170·92	0·10	36·772	108·700	2·905
6	330·94	111·75	+0·09	36·657	108·857	–2·903
8	287·03	52·58	0·07	36·552	109·014	2·900
10	243·11	353·39	+0·05	36·455	109·172	–2·897

Greenwich Noon.		P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B'.
1900.		°	°	°	"	"	"	°	°	°
May	12	9·17	112·431	−3·066	45·80	0·03	42·93	3·11	276·15	−3·27
	14	9·27	112·195	3·064	45·90	0·02	43·02	2·72	275·8	3·27
	16	9·36	111·954	3·061	45·99	0·02	43·10	2·32	275·2	3·27
	18	9·46	111·683	3·058	46·06	0·01	43·17	1·92	274·4	3·26
	20	9·56	111·461	3·055	46·12	0·01	43·23	1·52	273·1	3·26
	22	9·67	111·209	−3·051	46·17	0·00	43·27	1·11	270·8	−3·25
	24	9·78	110·956	3·048	46·21	0·00	43·31	0·71	265·9	3·25
	26	9·89	110·702	3·045	46·24	0·00	43·34	0·32	247·8	3·25
	28	10·00	110·447	3·042	46·25	0·00	43·35	0·22	149·4	3·24
	30	10·11	110·192	3·039	46·25	0·00	43·35	0·57	123·1	3·24
June	1	10·22	109·937	−3·035	46·23	0·00	43·33	0·97	109·9	−3·24
	3	10·32	109·685	3·031	46·21	0·01	43·31	1·38	107·3	3·23
	5	10·42	109·435	3·026	46·17	0·01	43·27	1·79	105·6	3·23
	7	10·53	109·188	3·021	46·12	0·02	43·22	2·19	104·6	3·22
	9	10·63	108·944	3·016	46·06	0·02	43·17	2·59	104·0	3·22
	11	10·73	108·705	−3·010	45·99	0·03	43·10	2·98	103·65	−3·21
	13	10·83	108·470	3·004	45·90	0·04	43·01	3·38	103·37	3·20
	15	10·92	108·242	2·998	45·80	0·05	42·92	3·76	103·14	3·20
	17	11·01	108·019	2·991	45·69	0·06	42·82	4·14	102·96	3·19
	19	11·10	107·804	2·985	45·57	0·07	42·71	4·51	102·82	3·18
	21	11·19	107·595	−2·978	45·43	0·08	42·58	4·88	102·72	−3·18
	23	11·27	107·394	2·972	45·29	0·10	42·45	5·24	102·64	3·17
	25	11·35	107·201	2·965	45·14	0·11	42·31	5·59	102·59	3·16
	27	11·42	107·017	2·958	44·98	0·12	42·16	5·93	102·55	3·16
	29	11·49	106·843	2·951	44·81	0·13	42·00	6·26	102·51	3·15
July	1	11·56	106·678	−2·943	44·64	0·15	41·84	6·58	102·47	−3·14
	3	11·62	106·522	2·936	44·46	0·16	41·67	6·90	102·43	3·13
	5	11·68	106·378	2·928	44·27	0·17	41·49	7·20	102·40	3·12
	7	11·73	106·244	2·921	44·08	0·18	41·31	7·49	102·38	3·12
	9	11·78	106·121	2·913	43·88	0·20	41·13	7·77	102·36	3·11
	11	11·83	106·009	−2·906	43·67	0·21	40·93	8·04	102·34	−3·10
	13	11·87	105·910	2·898	43·45	0·22	40·73	8·30	102·32	3·09
	15	11·91	105·821	2·890	43·23	0·23	40·52	8·54	102·30	3·08
	17	11·94	105·745	2·882	43·01	0·25	40·31	8·78	102·28	3·07
	19	11·97	105·680	2·874	42·78	0·26	40·10	9·00	102·26	3·07
	21	11·99	105·628	−2·867	42·55	0·27	39·88	9·21	102·24	−3·06
	23	12·01	105·587	2·859	42·32	0·28	39·67	9·41	102·21	3·05
	25	12·02	105·558	−2·852	42·08	0·29	39·44	9·60	102·19	−3·04

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	*B*.
1900.	°	°	°	m	°	°
May 12	199·19	294·21	+0·04	36·366	109·329	−2·894
14	155·27	235·04	0·03	36·288	109·486	2·891
16	111·35	175·87	0·02	36·220	109·643	2·889
18	67·43	116·69	0·02	36·162	109·800	2·886
20	23·51	57·51	+0·01	36·113	109·957	2·883
22	339·59	358·33	0·00	36·073	110·114	−2·880
24	295·66	299·14	0·00	36·044	110·272	2·877
26	251·73	239·94	0·00	36·025	110·430	2·874
28	207·80	180·74	0·00	36·016	110·588	2·871
30	163·86	121·54	0·00	36·017	110·745	2·868
June 1	119·91	62·33	0·00	36·027	110·902	−2·865
3	75·94	3·11	0·00	36·047	111·059	2·862
5	31·96	303·88	−0·01	36·077	111·217	2·858
7	347·97	244·64	0·02	36·117	111·375	2·855
9	303·98	185·39	0·03	36·167	111·533	2·852
11	259·98	126·13	0·04	36·227	111·691	−2·849
13	215·97	66·86	0·05	36·296	111·849	2·846
15	171·97	7·59	−0·06	36·373	112·007	2·843
17	127·95	308·30	0·08	36·459	112·165	2·840
19	83·91	249·00	0·09	36·555	112·323	2·837
21	39·86	189·68	0·11	36·661	112·480	−2·834
23	355·79	130·35	0·13	36·776	112·638	2·830
25	311·70	71·01	−0·14	36·897	112·796	2·827
27	267·60	11·65	0·16	37·027	112·954	2·824
29	223·49	312·28	0·17	37·166	113·113	2·821
July 1	179·36	252·89	0·19	37·313	113·271	−2·818
3	135·22	193·49	0·21	37·467	113·429	2·815
5	91·07	134·09	−0·23	37·627	113·587	2·811
7	46·91	74·67	0·25	37·796	113·745	2·808
9	2·73	15·23	0·27	37·971	113·903	2·804
11	318·53	315·77	0·29	38·153	114·061	−2·801
13	274·32	256·29	0·31	38·340	114·219	2·798
15	230·08	196·80	−0·32	38·532	114·377	2·794
17	185·83	137·29	0·34	38·732	114·535	2·790
19	141·56	77·78	0·36	38·937	114·694	2·787
21	97·29	18·24	0·38	39·147	114·853	−2·783
23	53·00	318·69	0·40	39·362	115·011	2·779
25	8·70	259·13	−0·41	39·580	115·17	−02·776

Greenwich Noon.		P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1900.		°	°	°	″	″	″	°	°	°
July	27	12·02	105·543	−2·844	41·84	0·30	39·21	9·77	102·16	−3·03
	29	12·03	105·539	2·836	41·60	0·31	38·99	9·94	102·14	3·03
	31	12·02	105·548	2·829	41·37	0·32	38·77	10·09	102·11	3·02
Aug.	2	12·01	105·568	2·821	41·13	0·33	38·55	10·22	102·08	3·01
	4	12·00	105·602	2·814	40·89	0·33	38·32	10·35	102·04	3·00
	6	11·98	105·648	−2·807	40·65	0·34	38·10	10·46	101·99	−2·99
	8	11·96	105·705	2·800	40·41	0·34	37·87	10·56	101·94	2·99
	10	11·93	105·774	2·793	40·17	0·35	37·65	10·65	101·89	2·98
	12	11·90	105·855	2·786	39·93	0·35	37·42	10·73	101·84	2·97
	14	11·86	105·949	2·779	39·69	0·35	37·20	10·80	101·79	2·97
	16	11·82	106·053	−2·772	39·46	0·35	36·99	10·85	101·73	−2·96
	18	11·78	106·169	2·765	39·22	0·35	36·76	10·89	101·67	2·95
	20	11·73	106·296	2·758	38·98	0·35	36·54	10·92	101·60	2·94
	22	11·67	106·435	2·751	38·75	0·35	36·32	10·94	101·53	2·93
	24	11·61	106·584	2·745	38·53	0·35	36·12	10·95	101·46	2·93
	26	11·55	106·745	−2·738	38·31	0·35	35·91	10·95	101·38	−2·92
	28	11·48	106·916	2·732	38·09	0·35	35·70	10·94	101·30	2·91
	30	11·41	107·098	2·726	37·86	0·34	35·49	10·92	101·22	2·91
Sept.	1	11·33	107·290	2·720	37·64	0·34	35·28	10·89	101·13	2·90
	3	11·25	107·492	2·714	37·43	0·34	35·08	10·84	101·04	2·90
	5	11·16	107·704	−2·708	37·22	0·33	34·88	10·79	100·94	−2·89
	7	11·07	107·926	2·702	37·02	0·33	34·69	10·73	100·84	2·88
	9	10·97	108·157	2·696	36·82	0·32	34·51	10·66	100·74	2·88
	11	10·88	108·398	2·690	36·62	0·31	34·32	10·57	100·64	2·87
	13	10·77	108·647	2·684	36·42	0·31	34·13	10·49	100·53	2·86
	15	10·67	108·905	−2·678	36·23	0·30	33·95	10·39	100·42	−2·86
	17	10·56	109·173	2·673	36·04	0·29	33·77	10·28	100·30	2·85
	19	10·44	109·449	2·667	35·85	0·28	33·60	10·16	100·18	2·84
	21	10·32	109·732	2·662	35·67	0·27	33·43	10·04	100·06	2·84
	23	10·20	110·026	2·656	35·49	0·27	33·26	9·91	99·93	2·83
	25	10·08	110·326	−2·651	35·32	0·26	33·10	9·77	99·80	−2·83
	27	9·95	110·634	2·645	35·15	0·25	32·94	9·62	99·67	2·82
	29	9·81	110·949	2·640	34·99	0·24	32·79	9·46	99·54	2·82
Oct.	1	9·68	111·272	2·634	34·83	0·23	32·64	9·30	99·40	2·81
	3	9·54	111·601	2·629	34·67	0·22	32·49	9·13	99·26	2·80
	5	9·39	111·938	−2·623	34·52	0·21	32·35	8·95	99·11	−2·80
	7	9·25	112·281	2·618	34·37	0·20	32·21	8·77	98·97	2·79
	9	9·09	112·630	−2·612	34·22	0·19	32·07	8·58	98·83	−2·79

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A − O.	B.
1900.	°	°	°	m	°	°
July 27	324·38	199·55	−0·42	39·804	115·328	−2·772
29	280·05	139·95	0·44	40·033	115·487	2·769
31	235·71	80·34	0·45	40·264	115·646	2·765
Aug. 2	191·34	20·72	0·46	40·500	115·804	2·761
4	146·95	321·09	0·47	40·736	115·963	2·757
6	102·55	261·45	−0·48	40·978	116·122	−2·754
8	58·14	201·79	0·49	41·222	116·281	2·750
10	13·72	142·11	0·50	41·468	116·440	2·746
12	329·29	82·41	0·50	41·716	116·598	2·742
14	284·86	22·70	0·51	41·963	116·757	2·739
16	240·42	322·98	−0·51	42·214	116·916	−2·736
18	195·96	263·25	0·52	42·467	117·075	2·732
20	151·48	203·51	0·52	42·720	117·234	2·728
22	106·98	143·76	0·52	42·974	117·393	2·724
24	62·45	84·00	0·52	43·228	117·552	2·720
26	17·92	24·23	−0·52	43·483	117·711	−2·716
28	333·39	324·45	0·52	43·738	117·870	2·712
30	288·86	264·66	0·52	43·992	118·029	2·708
Sept. 1	244·32	204·85	0·52	44·246	118·188	2·704
3	199·77	145·03	0·51	44·498	118·347	2·701
5	155·20	85·21	−0·51	44·749	118·506	−2·697
7	110·62	25·38	0·50	45·000	118·665	2·693
9	66·04	325·54	0·50	45·248	118·825	2·689
11	21·45	265·69	0·49	45·496	118·984	2·685
13	336·86	205·82	0·48	45·741	119·144	2·681
15	292·26	145·95	−0·47	45·985	119·304	−2·677
17	247·65	86·08	0·46	46·227	119·463	2·673
19	203·03	26·20	0·45	46·465	119·623	2·669
21	158·40	326·31	0·44	46·701	119·783	2·664
23	113·75	266·42	0·43	46·933	119·943	2·660
25	69·11	206·53	−0·42	47·162	120·102	−2·656
27	24·47	146·63	0·41	47·389	120·262	2·652
29	339·82	86·72	0·40	47·612	120·422	2·648
Oct. 1	295·16	26·80	0·38	47·832	120·582	2·644
3	250·50	326·88	0·37	48·046	120·741	2·639
5	205·84	266·96	−0·35	48·257	120·901	−2·635
7	161·17	207·03	0·34	48·464	121·061	2·630
9	116·50	147·10	−0·32	48·667	121·221	−2·626

Greenwich Noon.	P.	L—O.	B.	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d.	Q.	B′.
1900.	°	°	°	″	″	″	°	°	°
Oct. 11	8·94	112·986	−2·607	34·08	0·18	31·94	8·38	98·69	−2·78
13	8·79	113·348	2·602	33·95	0·17	31·82	8·18	98·55	2·78
15	8·63	113·714	2·596	33·82	0·16	31·70	7·98	98·40	2·77
17	8·47	114·088	2·591	33·70	0·15	31·59	7·76	98·23	2·76
19	8·30	114·466	2·585	33·58	0·14	31·47	7·54	98·05	2·76
21	8·14	114·851	−2·580	33·46	0·14	31·36	7·32	97·85	−2·75
23	7·97	115·240	2·575	33·35	0·13	31·26	7·09	97·63	2·75
25	7·80	115·634	2·569	33·24	0·12	31·16	6·86	97·39	2·74
27	7·63	116·034	2·564	33·14	0·11	31·06	6·62	97·14	2·73
29	7·46	116·436	2·559	33·04	0·10	30·97	6·37	96·88	2·73
31	7·28	116·844	−2·553	32·94	0·10	30·88	6·13	96·61	−2·72
Nov. 2	7·11	117·255	2·548	32·85	0·09	30·79	5·88	96·33	2·72
4	6·93	117·671	2·543	32·76	0·08	30·70	5·62	96·04	2·71
6	6·75	118·090	2·538	32·67	0·07	30·62	5·36	95·74	2·71
8	6·56	118·512	−2·532	32·59	0·07	30·54	5·10	95·42	−2·70

The position of *Jupiter's* North Pole is assumed to be R.A. $17^h\ 51^m\ 58^s{\cdot}69$, N.P.D. $25°\ 26'\ 23''{\cdot}4$ at the beginning of 1899, and R.A. $17^h\ 51^m\ 58^s{\cdot}95$, N.P.D. $25°\ 26'\ 24''{\cdot}1$ at the beginning of 1900.

P denotes the position angle of the northern extremity of *Jupiter's* axis, reckoned eastward from the northernmost point of the disc.

$L-O+180°$, $\Lambda-O+180°$ are the jovicentric longitudes of the Earth and Sun respectively, reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; B, *B* are the jovicentric latitudes of the Earth and Sun above the planet's equator.

B′ is the jovigraphical latitude of the centre of the disc, and is obtained by increasing B by $\frac{1}{15}$ of itself.

The equatorial and polar diameters depend, as before, on Professor Barnard's measures, the assumed values at distance unity being $200''{\cdot}32$ and $187''{\cdot}75$ respectively.

The assumed time for light to traverse the unit distance is $498^s{\cdot}92$, this being the same value as that used by Mr. Marth.

d denotes the jovicentric angle between the Earth and Sun.

Q denotes the position angle of the point of greatest phase, and is reckoned eastward from the northernmost point of the disc. It also gives the position angle of the shadows of the satellites measured from the satellites themselves. I have substituted Q for the angle *w* tabulated in recent years, as probably more useful to most observers.

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O.	B.
1900.	°	°	°	m	°	°
Oct. 11	71·82	87·16	−0·31	48·865	121·381	−2·621
13	27·14	27·22	0·30	49·057	121·541	2·617
15	342·46	327·28	0·28	49·245	121·701	2·612
17	297·77	267·33	0·27	49·429	121·861	2·609
19	253·08	207·39	0·25	49·607	122·021	2·604
21	208·39	147·44	−0·24	49·781	122·181	−2·599
23	163·70	87·49	0·23	49·948	122·341	2·594
25	119·01	27·54	0·21	50·111	122·502	2·590
27	74·32	327·59	0·20	50·268	122·662	2·585
29	29·62	267·64	0·19	50·419	122·822	2·580
31	344·93	207·68	−0·17	50·564	122·982	−2·575
Nov. 2	300·23	147·72	0·16	50·701	123·143	2·571
4	255·53	87·76	0·14	50·835	123·303	2·566
6	210·83	27·80	0·13	50·958	123·463	2·561
8	166·12	327·83	−0·11	51·078	123·624	−2·556

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero-meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians which bisect the illuminated disc. The great red spot will follow the zero-meridian of System II. by about one hour.

The quantities in the Ephemeris are to be interpolated directly for the times for which they are required, the equation of light having been already applied.

The following is a list of Greenwich mean times when the adopted zero-meridians in the two systems will pass the middle of the illuminated disc.

System I.

G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m	G.M.T. 1899. d	h	m
Dec. 17	4	45·26	Dec. 21	7	11·35	Dec. 25	9	37·39	Dec. 29	12	3·37
	14	35·87		17	1·96		19	27·98		21	53·97
18	0	26·48	22	2	52·56	26	5	18·58	30	7	44·56
	10	17·10		12	43·16		15	9·18		17	35·16
	20	7·71		22	33·77	27	0	59·78	31	3	25·76
19	5	58·31	23	8	24·37		10	50·38		13	16·34
	15	48·93		18	14·98		20	40·98		23	6·93
20	1	39·53	24	4	5·58	28	6	31·58	1900.		
	11	30·14		13	56·18		16	22·17	Jan. 1	8	57·52
	21	20·75		23	46·78	29	2	12·77		18	48·10

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Jan.	2	4	38·69	Jan.	18	4	31·23	Feb.	3	4	22·82	Feb.	19	4	13·37
		14	29·28			14	21·79			14	13·36			14	3·89
	3	0	19·86		19	0	12·35		4	0	3·89			23	54·40
		10	10·44			10	2·91			9	54·43		20	9	44·91
		20	1·03			19	53·47			19	44·97			19	35·42
	4	5	51·62		20	5	44·03		5	5	35·51		21	5	25·93
		15	42·20			15	34·59			15	26·05			15	16·44
	5	1	32·79		21	1	25·15		6	1	16·58		22	1	6·95
		11	23·38			11	15·71			11	7·11			10	57·46
		21	13·97			21	6·27			20	57·65			20	47·97
	6	7	4·56		22	6	56·83		7	6	48·18		23	6	38·48
		16	55·14			16	47·39			16	38·71			16	28·99
	7	2	45·72		23	2	37·95		8	2	29·25		24	2	19·49
		12	36·30			12	28·51			12	19·78			12	10·00
		22	26·88			22	19·07			22	10·31			22	0·50
	8	8	17·46		24	8	9·63		9	8	0·84		25	7	51·01
		18	8·04			18	0·19			17	51·37			17	41·52
	9	3	58·62		25	3	50·74		10	3	41·89		26	3	32·03
		13	49·20			13	41·30			13	32·42			13	22·54
		23	39·78			23	31·85			23	22·94			23	13·04
	10	9	30·35		26	9	22·40		11	9	13·46		27	9	3·54
		19	20·93			19	12·95			19	3·99			18	54·04
	11	5	11·50		27	5	3·50		12	4	54·52		28	4	44·54
		15	2·08			14	54·06			14	45·04			14	35·04
	12	0	51·65		28	0	44·61		13	0	35·57	Mar.	1	0	25·54
		10	43·22			10	35·17			10	26·10			10	16·04
		20	33·80			20	25·73			20	16·62			20	6·53
	13	6	24·37		29	6	16·27		14	6	7·15		2	5	57·03
		16	14·95			16	6·82			15	57·67			15	47·52
	14	2	5·52		30	1	57·37		15	1	48·19		3	1	38·01
		11	56·10			11	47·91			11	38·71			11	28·50
		21	46·67			21	38·46			21	29·23			21	18·99
	15	7	37·25		31	7	29·01		16	7	19·75		4	7	9·48
		17	27·82			17	19·55			17	10·27			16	59·97
	16	3	18·39	Feb.	1	3	10·10		17	3	0·79		5	2	50·46
		13	8·96			13	0·64			12	51·31			12	40·95
		22	59·53			22	51·19			22	41·82			22	31·44
	17	8	50·10		2	8	41·74		18	8	32·34		6	8	21·93
		18	40·67			18	32·28			18	22·86			18	12·42

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Mar.	7	4	2·91	Mar.	23	3	51·39	Apr.	8	3	38·88	Apr.	24	3	25·55
		13	53·39			13	41·86			13	29·31			13	15·97
		23	43·87			23	32·32			23	19·75			23	6·38
	8	9	34·35		24	9	22·78		9	9	10·18		25	8	56·79
		19	24·84			19	13·24			19	0·61			18	47·21
	9	5	15·32		25	5	3·69		10	4	51·05		26	4	37·63
		15	5·80			14	54·16			14	41·48			14	28·05
	10	0	56·28		26	0	44·61		11	0	31·91		27	0	18·46
		10	46·76			10	35·06			10	22·35			10	8·87
		20	37·23			20	25·52			20	12·78			19	59·28
	11	6	27·71		27	6	15·97		12	6	3·21		28	5	49·70
		16	18·19			16	6·43			15	53·64			15	40·11
	12	2	8·67		28	1	56·88		13	1	44·07		29	1	30·53
		11	59·15			11	47·34			11	34·50			11	20·94
		21	49·63			21	37·79			21	24·93			21	11·35
	13	7	40·11		29	7	28·25		14	7	15·36		30	7	1·77
		17	30·59			17	18·70			17	5·79			16	52·18
	14	3	21·06		30	3	9·16		15	2	56·22	May	1	2	42·59
		13	11·54			12	59·60			12	46·65			12	33·01
		23	2·02			22	50·06			22	37·08			22	23·42
	15	8	52·50		31	8	40·50		16	8	27·51		2	8	13·83
		18	42·97			18	30·96			18	17·94			18	4·24
	16	4	33·45	Apr.	1	4	21·40		17	4	8·37		3	3	54·65
		14	23·93			14	11·85			13	58·80			13	45·06
	17	0	14·40		2	0	2·29			23	49·22			23	35·47
		10	4·88			9	52·74		18	9	39·65		4	9	25·88
		19	55·35			19	43·18			19	30·07			19	16·29
	18	5	45·82		3	5	33·63		19	5	20·50		5	5	6·69
		15	36·29			15	24·07			15	10·92			14	57·10
	19	1	26·76		4	1	14·52		20	1	1·34		6	0	47·51
		11	17·24			11	4·95			10	51·76			10	37·92
		21	7·70			20	55·40			20	42·19			20	28·33
	20	6	58·16		5	6	45·84		21	6	32·61		7	6	18·73
		16	48·62			16	36·27			16	23·03			16	9·14
	21	2	39·08		6	2	26·71		22	2	13·45		8	1	59·55
		12	29·55			12	17·15			12	3·87			11	49·96
		22	20·01			22	7·58			21	54·29			21	40·37
	22	8	10·47		7	7	58·01		23	7	44·71		9	7	30·78
		18	0·93			17	48·45			17	35·13			17	21·18

System I.

1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m
May	10	3	11·59	May	26	2	57·56	June	11	2	44·10
		13	2·01			12	47·97			12	34·53
		22	52·42			22	38·38			22	24·96
	11	8	42·82		27	8	28·80		12	8	15·40
		18	33·23			18	19·21			18	5·84
	12	4	23·64		28	4	9·63		13	3	56·28
		14	14·04			14	0·04			13	46·73
	13	0	4·45			23	50·46			23	37·17
		9	54·86		29	9	40·87		14	9	27·61
		19	45·27			19	31·29			19	18·05
	14	5	35·69		30	5	21·71		15	5	8·49
		15	26·10			15	12·13			14	58·93
	15	1	16·52		31	1	2·55		16	0	49·38
		11	6·93			10	52·97			10	39·83
		20	57·35			20	43·39			20	30·28
	16	6	47·76	June	1	6	33·81		17	6	20·73
		16	38·16			16	24·23			16	11·18
	17	2	28·57		2	2	14·65		18	2	1·63
		12	18·98			12	5·08			11	52·08
		22	9·39			21	55·50			21	42·53
	18	7	59·80		3	7	45·92		19	7	32·98
		17	50·21			17	36·35			17	23·44
	19	3	40·62		4	3	26·77		20	3	13·89
		13	31·03			13	17·19			13	4·34
		23	21·43			23	7·62			22	54·80
	20	9	11·84		5	8	58·04		21	8	45·26
		19	2·25			18	48·47			18	35·72
	21	4	52·66		6	4	38·90		22	4	26·18
		14	43·07			14	29·33			14	16·64
	22	0	33·48		7	0	19·76		23	0	7·11
		10	23·88			10	10·19			9	57·58
		20	14·29			20	0·63			19	48·05
	23	6	4·70		8	5	51·06		24	5	38·51
		15	55·11			15	41·49			15	28·98
	24	1	45·52		9	1	31·92		25	1	19·45
		11	35·93			11	22·36			11	9·92
		21	26·33			21	12·79			21	0·39
	25	7	16·74		10	7	3·23		26	6	50·86
		17	7·15			16	53·66			16	41·34

1900.	G.M.T. d	h	m
June	27	2	31·82
		12	22·30
		22	12·78
	28	8	3·26
		17	53·74
	29	3	44·22
		13	34·70
		23	25·18
	30	9	15·66
		19	6·14
July	1	4	56·62
		14	47·11
	2	0	37·59
		10	28·08
		20	18·57
	3	6	9·05
		15	59·54
	4	1	50·03
		11	40·51
		21	31·00
	5	7	21·49
		17	11·98
	6	3	2·48
		12	52·98
		22	43·48
	7	8	33·97
		18	24·47
	8	4	14·97
		14	5·47
		23	55·97
	9	9	46·48
		19	36·98
	10	5	27·48
		15	17·99
	11	1	8·50
		10	59·01
		20	49·52
	12	6	40·03
		16	30·54

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
July	13	2	21·05	July	29	2	11·89	Aug.	14	2	4·11	Aug.	30	1	57·55
		12	11·56			12	2·44			11	54·69			11	48·17
		22	2·07			21	52·99			21	45·27			21	38·78
	14	7	52·58		30	7	43·55		15	7	35·86		31	7	29·40
		17	43·10			17	34·10			17	26·45			17	20·01
	15	3	33·62		31	3	24·66		16	3	17·04	Sept.	1	3	10·63
		13	24·14			13	15·22			13	7·63			13	1·24
		23	14·66			23	5·78			22	58·22			22	51·86
	16	9	5·18	Aug.	1	8	56·34		17	8	48·82		2	8	42·48
		18	55·70			18	46·90			18	39·41			18	33·10
	17	4	46·23		2	4	37·46		18	4	30·00		3	4	23·72
		14	36·76			14	28·03			14	20·60			14	14·35
	18	0	27·29		3	0	18·59		19	0	11·20		4	0	4·98
		10	17·82			10	9·16			10	1·79			9	55·60
		20	8·35			19	59·72			19	52·39			19	46·23
	19	5	58·88		4	5	50·28		20	5	42·98		5	5	36·85
		15	49·41			15	40·85			15	33·58			15	27·47
	20	1	39·95		5	1	31·42		21	1	24·18		6	1	18·10
		11	30·48			11	21·99			11	14·78			11	8·72
		21	21·02			21	12·56			21	5·38			20	59·34
	21	7	11·56		6	7	3·14		22	6	55·98		7	6	49·97
		17	2·09			16	53·70			16	46·59			16	40·59
	22	2	52·63		7	2	44·28		23	2	37·20		8	2	31·22
		12	43·17			12	34·85			12	27·81			12	21·84
		22	33·70			22	25·43			22	18·41			22	12·46
	23	8	24·24		8	8	16·00		24	8	9·01		9	8	3·09
		18	14·78			18	6·58			17	59·62			17	53·71
	24	4	5·32		9	3	57·15		25	3	50·23		10	3	44·34
		13	55·86			13	47·73			13	40·84			13	34·97
		23	46·40			23	38·30			23	31·44			23	25·60
	25	9	36·94		10	9	28·88		26	9	22·05		11	9	16·23
		19	27·49			19	19·46			19	12·66			19	6·86
	26	5	18·04		11	5	10·04		27	5	3·27		12	4	57·49
		15	8·58			15	0·62			14	53·88			14	48·12
	27	0	59·13		12	0	51·20		28	0	44·49		13	0	38·75
		10	49·68			10	41·77			10	35·10			10	29·38
		20	40·23			20	32·36			20	25·71			20	20·01
	28	6	30·78		13	6	22·94		29	6	16·32		14	6	10·64
		16	21·33			16	13·52			16	6·94			16	1·28

System I.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Sept.	15	1	51·92	Sept.	29	0	33·76	Oct.	12	13	25·30	Oct.	26	2	17·08
		11	42·55			10	24·41			23	15·96			12	7·75
		21	33·19			20	15·06		13	9	6·61			21	58·41
	16	7	23·82		30	6	5·71			18	57·27		27	7	49·07
		17	14·45			15	56·36		14	4	47·93			17	39·73
	17	3	5·09	Oct.	1	1	47·01			14	38·58		28	3	30·39
		12	55·73			11	37·66		15	0	29·25			13	21·06
		22	46·37			21	28·31			10	19·90			23	11·72
	18	8	37·00		2	7	18·96			20	10·56		29	9	2·38
		18	27·64			17	9·61		16	6	1·22			18	53·04
	19	4	18·26		3	3	0·26			15	51·88		30	4	43·70
		14	8·93			12	50·91		17	1	42·54			14	34·37
		23	59·57			22	41·56			11	33·20		31	0	25·03
	20	9	50·22		4	8	32·22			21	23·86			10	15·69
		19	40·86			18	22·88		18	7	14·52			20	6·35
	21	5	31·50		5	4	13·53			17	5·18	Nov.	1	5	57·01
		15	22·14			14	4·19		19	2	55·84			15	47·67
	22	1	12·79			23	54·84			12	46·50		2	1	38·33
		11	3·44		6	9	45·49			22	37·16			11	28·99
		20	54·09			19	36·15		20	8	27·82			21	19·66
	23	6	44·73		7	5	26·80			18	18·48		3	7	10·32
		16	35·37			15	17·46		21	4	9·14			17	0·99
	24	2	26·01		8	1	8·11			13	59·80		4	2	51·65
		12	16·66			10	58·76			23	50·46			12	42·31
		22	7·30			20	49·42		22	9	41·12			22	32·98
	25	7	57·94		9	6	40·07			19	31·79		5	8	23·65
		17	48·58			16	30·72		23	5	22·45			18	14·31
	26	3	39·23		10	2	21·38			15	13·11		6	4	4·97
		13	29·88			12	12·03		24	1	3·78			13	55·63
		23	20·53			22	2·69			10	54·44			23	46·30
	27	9	11·17		11	7	53·34			20	45·10		7	9	36·97
		19	1·82			17	43·99		25	6	35·76			19	27·63
	28	4	52·47		12	3	34·65			16	26·42		8	5	18·29
		14	43·11												

[redacted]

System II.

1899.	G.M.T. d	h	m	1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m
Dec.	17	1	14·13	Jan.	1	18	33·78	Jan.	17	21	48·28	Feb.	3	1	1·84
		11	9·93		2	4	29·55		18	7	44·02			10	57·56
		21	5·72			14	25·32			17	39·76			20	53·28
	18	7	1·51		3	0	21·09		19	3	35·50		4	6	49·90
		16	57·30			10	16·85			13	51·24			16	44·71
	19	2	53·10			20	12·62			13	27·02		5	2	40·43
		12	48·89		4	6	8·39		20	9	22·76			12	36·14
		22	44·68			16	4·15			19	18·50			22	31·86
	20	8	40·46		5	1	59·92		21	5	14·23		6	8	27·57
		18	36·25			11	55·68			15	9·97			18	23·29
	21	4	32·03			21	51·44		22	1	5·71		7	4	19·00
		14	27·82		6	7	47·20			11	1·44			14	14·71
	22	0	23·60			17	42·97			20	57·18		8	0	10·42
		10	19·38		7	3	38·73		23	6	52·91			10	6·13
		20	15·16			13	34·49			16	48·65			20	1·84
	23	6	10·94			23	30·25		24	2	44·39		9	5	57·55
		16	6·72		8	9	26·02			12	40·13			15	53·26
	24	2	2·50			19	21·77			22	35·86		10	1	48·97
		11	58·28		9	5	17·53		25	8	31·59			11	44·68
		21	54·06			15	13·28			18	27·32			21	40·39
	25	7	49·84		10	1	9·04		26	4	23·05		11	7	36·10
		17	45·62			11	4·80			14	18·78			17	31·81
	26	3	41·40			21	0·56		27	0	14·51		12	3	27·51
		13	37·18		11	6	56·31			10	10·24			13	23·22
		23	32·96			16	52·07			20	5·97			23	18·92
	27	9	28·73		12	2	47·82		28	6	1·70		13	9	14·61
		19	24·51			12	43·57			15	57·43			19	10·31
	28	5	20·28			22	39·32		29	1	53·16		14	5	6·01
		15	16·06		13	8	35·07			11	48·89			15	1·71
	29	1	11·83			18	30·82			21	44·62		15	0	57·40
		11	7·61		14	4	26·56		30	7	40·34			10	53·10
		21	3·38			14	22·31			17	36·07			20	48·79
	30	6	59·15		15	0	18·06		31	3	31·80		16	6	44·49
		16	54·92			10	13·81			13	27·52			16	40·18
	31	2	50·69			20	9·56			23	23·24		17	2	35·88
		12	46·46		16	6	5·31	Feb.	1	9	18·97			12	31·57
		22	42·24			16	1·06			19	14·69			22	27·26
					17	1	56·80		2	5	10·41		18	8	22·95
1900 Jan.	1	8	38·01			11	52·54			15	6·13			18	18·65

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Feb.	19	4	14·34	Mar.	7	7	25·82	Mar.	23	10	36·24	Apr.	8	13	45·59
		14	10·03			17	21·47			20	31·87			23	41·20
	20	0	5·72		8	3	17·14		24	6	27·51		9	9	36·81
		10	1·41			13	12·80			16	23·15			19	32·42
		19	57·10			23	8·47		25	2	18·78		10	5	28·03
	21	5	52·79		9	9	4·13			12	14·41			15	23·65
		15	48·48			18	59·78			22	10·04		11	1	19·26
	22	1	44·17		10	4	55·45		26	8	5·67			11	14·87
		11	39·86			14	51·11			18	1·30			21	10·48
		21	35·55		11	0	46·77		27	3	56·92		12	7	6·09
	23	7	31·23			10	42·44			13	52·55			17	1·70
		17	26·92			20	38·10			23	48·13		13	2	57·30
	24	3	22·61		12	6	33·75		28	9	43·76			12	52·91
		13	18·30			16	29·41			19	39·39			22	48·51
		23	13·98		13	2	25·06		29	5	35·02		14	8	44·12
	25	9	9·66			12	20·71			15	30·65			18	39·72
		19	5·34			22	16·36		30	1	26·28		15	4	35·33
	26	5	1·02		14	8	12·02			11	21·91			14	30·93
		14	56·70			18	7·67			21	17·54		16	0	26·52
	27	0	52·38		15	4	3·32		31	7	13·17			10	22·12
		10	48·06			13	58·97			17	8·80			20	17·72
		20	43·74			23	54·62	Apr.	1	3	4·43		17	6	13·32
	28	6	39·42		16	9	50·27			13	0·05			16	8·92
		16	35·10			19	45·92			22	55·68		18	2	4·52
Mar.	1	2	30·78		17	5	41·57		2	8	51·31			12	0·12
		12	26·45			15	37·22			18	46·93			21	55·72
		22	22·12		18	1	32·87		3	4	42·56		19	7	51·32
	2	8	17·79			11	28·52			14	38·18			17	46·92
		18	13·46			21	24·17		4	0	33·81		20	3	42·52
	3	4	9·13		19	7	19·82			10	29·43			13	38·12
		14	4·80			17	15·46			20	25·05			23	33·72
	4	0	0·47		20	3	11·10		5	6	20·67		21	9	29·32
		9	56·14			13	6·75			16	16·28			19	24·91
		19	51·81			23	2·39		6	2	11·89		22	5	20·51
	5	5	47·48		21	8	58·04			12	7·51			15	16·11
		15	43·15			18	53·68			22	3·12		23	1	11·71
	6	1	38·81		22	4	49·32		7	7	58·74			11	7·30
		11	34·48			14	44·96			17	54·36			21	2·90
		21	30·15		23	0	40·60		8	3	49·98		24	6	58·49

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Apr.	24	16	54·08	May	10	20	1·98	May	26	23	9·80	June	12	2	18·20
	25	2	49·67		11	5	57·56		27	9	5·39			12	13·82
		12	45·26			15	53·14			19	0·98			22	9·43
		22	40·85		12	1	48·73		28	4	56·57		13	8	5·05
	26	8	36·43			11	44·32			14	52·16			18	0·67
		18	32·02			21	39·90		29	0	47·75		14	3	56·27
	27	4	27·61		13	7	35·49			10	43·34			13	51·90
		14	23·20			17	31·07			20	38·93			23	47·52
	28	0	18·79		14	3	26·65		30	6	34·52		15	9	43·15
		10	14·38			13	22·24			16	30·11			19	38·77
		20	9·97			23	17·82		31	2	25·70		16	5	34·40
	29	6	5·56		15	9	13·41			12	21·30			15	30·02
		16	1·15			19	9·00			22	16·89		17	1	25·65
	30	1	56·74		16	5	4·58	June	1	8	12·48			11	21·27
		11	52·33			15	0·16			18	8·07			21	16·90
		21	47·92		17	0	55·75		2	4	3·66		18	7	12·52
May	1	7	43·51			10	51·33			13	59·26			17	8·15
		17	39·10			20	46·92			23	54·86		19	3	3·78
	2	3	34·69		18	6	42·50		3	9	50·46			12	59·41
		13	30·28			16	38·09			19	46·06			22	55·04
		23	25·87		19	2	33·67		4	5	41·66		20	8	50·67
	3	9	21·45			12	29·26			15	37·26			18	46·31
		19	17·04			22	24·84		5	1	32·86		21	4	41·94
	4	5	12·62		20	8	20·43			11	28·46			14	37·58
		15	8·21			18	16·01			21	24·07		22	0	33·22
	5	1	3·79		21	4	11·60		6	7	19·67			10	28·87
		10	59·38			14	7·18			17	15·28			20	24·50
		20	54·96		22	0	2·77		7	3	10·88		23	6	20·15
	6	6	50·55			9	58·35			13	6·49			16	15·79
		16	46·13			19	53·94			23	2·09		24	2	11·44
	7	2	41·72		23	5	49·52		8	8	57·70			12	7·09
		12	37·31			15	45·11			18	53·31			22	2·73
		22	32·89		24	1	40·69		9	4	48·92		25	7	58·38
	8	8	28·48			11	36·28			14	44·53			17	54·02
		18	24·06			21	31·86		10	0	40·15		26	3	49·67
	9	4	19·64		25	7	27·45			10	35·75			13	45·32
		14	15·22			17	23·03			20	31·36			23	40·97
	10	0	10·81		26	3	18·62		11	6	26·97		27	9	36·61
		10	6·39			13	14·21			16	22·58			19	32·27

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
June	28	5	27·92	July	14	8	39·20	July	30	11	52·06	Aug.	15	15	6·35
		15	23·58			18	34·89			21	47·80		16	1	2·12
	29	1	19·23		15	4	30·58		31	7	43·53			10	57·89
		11	14·89			14	26·28			17	39·26			20	53·66
		21	10·54		16	0	21·99	Aug.	1	3	35·00		17	6	49·44
	30	7	6·20			10	17·68			13	30·74			16	45·21
		17	1·86			20	13·39			23	26·48		18	2	40·98
July	1	2	57·53		17	6	9·09		2	9	22·21			12	36·75
		12	53·19			16	4·80			19	17·95			22	32·52
		22	48·86		18	2	0·50		3	5	13·69		19	8	28·29
	2	8	44·52			11	56·21			15	9·43			18	24·06
		18	40·19			21	51·91		4	1	5·17		20	4	19·83
	3	4	35·85		19	7	47·62			11	0·92			14	15·61
		14	31·52			17	43·33			20	56·67		21	0	11·38
	4	0	27·18		20	3	39·04		5	6	52·43			10	7·16
		10	22·85			13	34·75			16	48·19			20	2·93
		20	18·51			23	30·46		6	2	43·95		22	5	58·71
	5	6	14·18		21	9	26·17			12	39·72			15	54·48
		16	9·85			19	21·87			22	35·48		23	1	50·27
	6	2	5·52		22	5	17·59		7	8	31·24			11	46·05
		12	1·19			15	13·30			18	26·99			21	41·83
		21	56·87		23	1	9·02		8	4	22·75		24	7	37·62
	7	7	52·54			11	4·73			14	18·51			17	33·41
		17	48·23			21	0·45		9	0	14·27		25	3	29·19
	8	3	43·91		24	6	56·16			10	10·03			13	24·98
		13	39·59			16	51·88			20	5·79			23	20·76
		23	35·27		25	2	47·59		10	6	1·56		26	9	16·54
	9	9	30·95			12	43·31			15	57·07			19	12·33
		19	26·63			22	39·03		11	1	52·84		27	5	8·12
	10	5	22·31		26	8	34·76			11	48·61			15	3·91
		15	17·99			18	30·48			21	44·39		28	0	59·69
	11	1	13·68		27	4	26·21		12	7	40·16			10	55·49
		11	9·36			14	21·94			17	35·94			20	51·28
		21	5·05		28	0	17·67		13	3	31·71		29	6	47·07
	12	7	0·74			10	13·40			13	27·49			16	42·87
		16	56·44			20	9·13			23	23·26		30	2	38·66
	13	2	52·13		29	6	4·87		14	9	19·04			12	34·45
		12	47·82			16	0·60			19	14·81			22	30·25
		22	43·51		30	1	56·33		15	5	10·58		31	8	26·05

System II.

	G.M.T.				G.M.T.				G.M.T.				G.M.T.		
1900.	d	h	m	1900.	d	h	m	1900.	d	h	m	1900.	d	h	m
Aug.	31	18	21·85	Sept.	16	21	38·29	Oct.	3	0	55·43	Oct.	19	4	13·02
Sept.	1	4	17·64		17	7	34·11			10	51·27			14	8·86
		14	13·44			17	29·92			20	47·11		20	0	4·70
	2	0	9·23		18	3	25·74		4	6	42·94			10	0·54
		10	5·03			13	21·55			16	38·77			19	56·38
		20	0·83			23	17·37		5	2	34·60		21	5	52·22
	3	5	56·62		19	9	13·19			12	30·43			15	48·06
		15	52·42			19	9·01			22	26·26		22	1	43·90
	4	1	48·22		20	5	4·83		6	8	22·10			11	39·74
		11	44·02			15	0·65			18	17·93			21	35·58
		21	39·82		21	0	56·48		7	4	13·76		23	7	31·42
	5	7	35·63			10	52·30			14	9·59			17	27·26
		17	31·44			20	48·12		8	0	5·42		24	3	23·10
	6	3	27·24		22	6	43·94			10	1·26			13	18·94
		13	23·05			16	39·77			19	57·09			23	14·78
		23	18·85		23	2	35·59		9	5	52·93		25	9	10·62
	7	9	14·65			12	31·41			15	48·76			19	6·46
		19	10·46			22	27·23		10	1	44·59		26	5	2·30
	8	5	6·27		24	8	23·06			11	40·43			14	58·14
		15	2·07			18	18·89			21	36·26		27	0	53·98
	9	0	57·88		25	4	14·72		11	7	32·10			10	49·82
		10	53·69			14	10·54			17	27·93			20	45·66
		20	49·50		26	0	6·36		12	3	23·77		28	6	41·50
	10	6	45·31			10	2·19			13	19·60			16	37·34
		16	41·12			19	58·01			23	15·43		29	2	33·17
	11	2	36·93		27	5	53·83		13	9	11·27			12	29·02
		12	32·74			15	49·66			19	7·11			22	24·86
		22	28·54		28	1	45·48		14	5	2·95		30	8	20·71
	12	8	24·35			11	41·31			14	58·79			18	16·54
		18	20·16			21	37·14		15	0	54·63		31	4	12·39
	13	4	15·97		29	7	32·97			10	50·47			14	8·23
		14	11·78			17	28·80			20	46·31	Nov.	1	0	4·08
	14	0	7·59		30	3	24·63		16	6	42·15			9	59·92
		10	3·40			13	20·46			16	37·99			19	55·77
		19	59·22			23	16·29		17	2	33·83		2	5	51·61
	15	5	55·04	Oct.	1	9	12·12			12	29·66			15	47·45
		15	50·85			19	7·95			22	25·50		3	1	43·30
	16	1	46·66		2	5	3·77		18	8	21·34			11	39·14
		11	42·47			14	59·60			18	17·18			21	34·99

System II.

1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m	1900.	G.M.T. d	h	m
Nov.	4	7	30·83	Nov.	5	13	18·37	Nov.	6	19	5·90	Nov.	7	14	57·59
		17	26·68			23	14·21		7	5	1·75		8	0	53·43
	5	3	22·52		6	9	10·06								

A list of the times of elongation of the fifth satellite is given in the *Connaissance des Temps* for 1900. The East and West elongations given there for 1899 require to be interchanged. This has been corrected in 1900.

It may be mentioned here that the *Connaissance des Temps* for 1899 and following years gives ephemerides for the satellites of *Mars*, *Saturn*, *Uranus* and *Neptune* in the same form as those formerly contributed to the *Monthly Notices* by Mr. Marth.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.:*
1899 *November* 15.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Professor G. H. DARWIN, M.A., LL.D., F.R.S., President, in the Chair.

Henry C. Plummer, B.A., The Owens College, Manchester; and
Clement Jennings Taylor, Derby Road, Kenilworth, Cape Town,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer, from personal knowledge, being appended :—

William Henry Robinson, Offenden, Walsall, Staffordshire (proposed by Sir R. S. Ball).

Sixty-four presents were announced as having been received since the last meeting, including amongst others :—

Photograph of the great refractor of the Potsdam Observatory, presented by the Observatory.

The theory of the Figure of the Earth carried to the second order of small quantities. By G. H. Darwin, F.R.S., Plumian Professor and Fellow of Trinity College, Cambridge; President of the Royal Astronomical Society.

Introduction.

As far as I know, Airy was the first to include quantities of the second order in investigating the theory of the Earth's figure; his paper is dated 1826, and is published in Part III. of the *Philosophical Transactions of the Royal Society* for that year.

He gave the formula for gravity which I have obtained below (§ 6, (40)). Our results would be *literatim* identical but that my e is expressed by $e \div (1-e)$ in his notation, and that I denote by $-f$ the quantity which he wrote as A. He also established equations, equivalent to my (13) and (14), which express the identity of the surfaces of equal density with the level surfaces. He remarked that these may be reduced to the form of differential equations, but he did not give the results, since he found himself unable to solve them, even for an assumed law of internal density. I have succeeded in solving these equations in this paper.

Airy further concluded that the Earth's surface must be depressed below the level of the true ellipsoid in middle latitudes. He gave no numerical estimate of this depression, but expressed the opinion that it must be very small.

In the second volume of his *Höhere Geodäsie*, Dr. Helmert has also investigated the formula for gravity to the second order of small quantities. The expression for gravity which has been compared with the results of pendulum experiments by Dr. Helmert was taken as having no term dependent on the fourth power of the sine of the latitude. The results of the experiments are somewhat irregular, and there was no apparent advantage in the inclusion of such a term; accordingly Dr. Helmert assumed that such a term is actually evanescent, and pointed out that this implies that the Earth's surface is elevated above the true ellipsoid, instead of being depressed below it, in middle latitudes. There can, I think, be no doubt that there should be depression, and it therefore seems as if it would be safer to adopt such a formula as that given below in § 6 (41) in future reductions of pendulum experiments.

In volume xix. (1889, pp. E, 1–84) of the *Annals of the Observatory of Paris* M. Callandreau has carried out an elaborate investigation of the problems considered in this paper. The publication of my work might, indeed, have been unnecessary were it not that my procedure is, as I think, simpler than his, and that my formulæ are presented in a more tractable shape. I have, however, in some respects, as for instance in the numerical

solution of the differential equations, carried the work somewhat further than he has done; but, on the other hand, he has considered several interesting points on which I do not touch. Our two methods differ in detail from first to last, and it would be rather troublesome to compare them from point to point. I have then been satisfied with the knowledge that we are travelling along parallel roads. M. Callandreau has also written a short but valuable note on the same subject in the *Bulletin Astronomique* for 1897. I refer to this paper in § 12.

Lastly Professor Wiechert has published an important memoir on the distribution of masses in the interior of the Earth in the *Transactions* of the Royal Society of Sciences of Göttingen (1897, pp. 221–243). He has there adduced weighty arguments in favour of the hypothesis that the Earth consists of an iron nucleus with a superstratum of rock. He also has taken into account quantities of the second order, and has calculated interesting numerical results corresponding to his theory. I refer to this paper in §§ 10, 12, and in the summary.

The first part of my paper contains the mathematical investigation, and this is followed by a summary and discussion of results.

Mathematical Investigation.

§ 1. *The Moments of Inertia and the Potential of a homogeneous Spheroid.*

The equation to the surface of a homogeneous oblate ellipsoid of revolution of density w whose semi-axes are a and $a(1-e)$ is

$$r^2\left(\frac{\cos^2\theta}{(1-e)^2}+\sin^2\theta\right)=a^2,$$

where r is the radius vector and θ the colatitude measured from the axis of revolution.

If the cubes and higher powers of e are neglected, the equation may be written

$$r=a\{1-e\cos^2\theta-\tfrac{3}{2}e^2\sin^2\theta\cos^2\theta\}.$$

Now let us consider a spheroid of which the equation is

$$r=a\{1-e\cos^2\theta+(f-\tfrac{3}{2}e^2)\sin^2\theta\cos^2\theta\},$$

where f is of the same order of magnitude as e^2.

This surface has ellipticity e, and the excess of its radius vector over that of the true ellipsoid is $af\sin^2\theta\cos^2\theta$. The maximum excess occurs in colatitude 45°, and it amounts to $\frac{1}{4}af$.

I now introduce the zonal harmonics—

$$P_2=\tfrac{3}{2}\cos^2\theta-\tfrac{1}{2},\qquad P_4=\tfrac{35}{8}\cos^4\theta-\tfrac{15}{4}\cos^2\theta+\tfrac{3}{8},$$

so that $\cos^2\theta=\frac{2}{3}P_2+\frac{1}{3}$, $\qquad \sin^2\theta\cos^2\theta=-\frac{8}{35}P_4+\frac{2}{21}P_2+\frac{2}{15}$.

Accordingly, the equation to the spheroid may be written

$$r=a\{1-\tfrac{1}{3}e-\tfrac{1}{5}e^2+\tfrac{2}{15}f-\tfrac{2}{3}(e+\tfrac{3}{14}e^2-\tfrac{1}{7}f)P_2+\tfrac{8}{35}(\tfrac{3}{2}e^2-f)P_4\} \quad (1)$$

This form of the equation will be needed hereafter, but for the present it is convenient to regard the body as consisting of a homogeneous ellipsoid of density w, and with semi-axes a and $a(1-e)$, together with the excess above the ellipsoid of a body of which the equation is

$$r=a\{1+\tfrac{2}{15}f+\tfrac{2}{21}fP_2-\tfrac{8}{35}fP_4\} \quad . \quad . \quad . \quad . \quad (2)$$

The developments will only be carried to the order e^2, and therefore we may regard this excess as a layer of surface density

$$wa(\tfrac{2}{15}f+\tfrac{2}{21}fP_2-\tfrac{8}{35}fP_4),$$

distributed over the surface of a sphere of radius a.

The mass of the excess is clearly $4\pi wa^3(\frac{2}{15}f)$, and the mass of the ellipsoid is $\frac{4}{3}\pi wa^3(1-e)$; hence the mass of the spheroid is given by

$$M=\tfrac{4}{3}\pi wa^3(1-e+\tfrac{2}{5}f) \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If ρ, θ, ϕ be the polar coordinates of a point whose Cartesian coordinates are x, y, z we have

$$x^2+y^2=\tfrac{2}{3}\rho^2(1-P_2), \quad \left\{\begin{matrix} x^2+z^2 \\ y^2+z^2 \end{matrix}\right.=\tfrac{2}{3}\rho^2(1+\tfrac{1}{2}P_2)\pm\tfrac{1}{2}\rho^2\sin^2\theta\cos 2\phi.$$

Now let C', A', denote the moments of inertia of the shell (2) about the axes of z, and of x or of y, and we have

$$\left\{\begin{matrix} C' \\ A' \end{matrix}\right.=\tfrac{2}{3}\iiint w\rho^4\left\{\begin{matrix} 1-P_2 \\ 1+\frac{1}{2}P_2 \end{matrix}\right.\sin\theta d\theta d\phi.$$

integrated throughout the layer comprised between the surface (2) and the sphere a.

Then, since $\int\rho^4 d\rho=\frac{1}{5}a^5\{\frac{2}{3}f+\frac{10}{21}fP_2-\frac{8}{7}fP_4\}$, and since the integrals over the surface of a sphere of a spherical harmonic, and also of the product of two harmonics of different orders vanish, we have

$$C'=4\pi wa^5\int_0^\pi(\tfrac{2}{15}f-\tfrac{2}{21}fP_2^2)\sin\theta d\theta.$$

$$A'=4\pi wa^5\int_0^\pi(\tfrac{2}{15}f+\tfrac{1}{21}fP_2^2)\sin\theta d\theta.$$

Also $\int_0^\pi P_2^2\sin\theta d\theta=\frac{2}{5}$, and therefore

$$C'=\tfrac{8}{15}\pi wa^5(\tfrac{4}{7}f), \quad A'=\tfrac{8}{15}\pi wa^5(\tfrac{5}{7}f).$$

Now denoting the moments of inertia of the homogeneous ellipsoid by C″, A″, we have

$$C''=\tfrac{8}{15}\pi wa^5(1-e), \quad A''=\tfrac{8}{15}\pi wa^5(1-2e+\tfrac{3}{2}e^2).$$

The sums $C'+C''$, $A'+A''$, give the moments of inertia of the spheroid ; so that

$$\left.\begin{aligned} C=\tfrac{8}{15}\pi wa^5(1-e+\tfrac{4}{7}f), \quad A=\tfrac{8}{15}\pi wa^5(1-2e+\tfrac{3}{2}e^2+\tfrac{5}{7}f),\\ C-A=\tfrac{8}{15}\pi wa^5(e-\tfrac{3}{2}e^2-\tfrac{1}{7}f). \end{aligned}\right\} \quad (4)$$

It is, in the next place, necessary to evaluate the potential of the spheroid both internally and externally, and I will begin by considering the part contributed by the shell defined by (2). It consists of a spherical shell of mass $\frac{8}{15}\pi wa^3f$ and radius a, together with surface density $\frac{2}{21}wafP_2-\frac{8}{35}wafP_4$. Accordingly, if U_e', U_i' denote the external and internal potentials

$$U_e'=\tfrac{8}{15}\pi wa^3\frac{f}{r}+\tfrac{4}{5}\pi\,.\,\tfrac{2}{21}waf\,.\,\frac{a^4}{r^3}P_2-\tfrac{4}{9}\pi\,.\,\tfrac{8}{35}waf\,.\,\frac{a^6}{r^5}P_4,$$

$$U_i'=\tfrac{8}{15}\pi wa^2f+\tfrac{4}{5}\pi\,.\,\tfrac{2}{21}waf\,.\,\frac{r^2}{a}P_2-\tfrac{4}{9}\pi\,.\,\tfrac{8}{35}waf\,.\,\frac{r^4}{a^3}P_4.$$

We have now to find the external and internal potentials of the ellipsoid, which may be denoted by U_e'', U_i''.

It is well known that the external potential of an ellipsoid of revolution of semi-major axis a, *eccentricity* η, and mass M' is

$$U_e''=\frac{M'}{r}\left\{1-\tfrac{1}{5}\frac{a^2\eta^2}{r^2}P_2+\tfrac{3}{35}\frac{a^4\eta^4}{r^4}P_4\ \ldots\right\}.$$

Also if $\eta=\sin\gamma$, the internal potential is

$$U_i''=\frac{3M'\gamma}{\sin\gamma}-\frac{3}{4}\frac{M'}{a^3\sin^3\gamma}(\gamma-\sin\gamma\cos\gamma)(x^2+y^2)$$
$$-\frac{3}{2}\frac{M'}{a^3\sin^3\gamma}(\tan\gamma-\gamma)z^2.$$

Now $$\tan\gamma-\gamma=\tfrac{1}{3}\eta^3(1+\tfrac{9}{10}\eta^2+\tfrac{43}{56}\eta^4+\ \ldots),$$

$$\gamma-\sin\gamma\cos\gamma=\tfrac{2}{3}\eta^3(1+\tfrac{3}{10}\eta^2+\tfrac{9}{56}\eta^4+\ \ldots).$$

Also $$(x^2+y^2)=\tfrac{2}{3}r^2(1-P_2), \quad z^2=\tfrac{2}{3}r^2(\tfrac{1}{2}+P_2).$$

Therefore

$$U_i''=\tfrac{3}{2}\frac{M'}{a}(1+\tfrac{1}{6}\eta^2+\tfrac{3}{40}\eta^4\ \ldots)-\tfrac{1}{2}\frac{M'r^2}{a^3}(1+\tfrac{1}{2}\eta^2+\tfrac{3}{8}\eta^4+\ \ldots)$$
$$-\tfrac{1}{5}\frac{M'r^2}{a^3}(\eta^2+\tfrac{13}{14}\eta^4\ \ldots)P_2.$$

But $\eta^2=2e(1-\frac{1}{2}e)$ and $M'=\frac{4}{3}\pi w a^3(1-e)$, and on substitution in the above formulæ it will be found that

$$U_e''=\frac{4}{3}\pi w\frac{a^3}{r}(1-e)-\frac{8}{15}\pi w\frac{a^5}{r^3}e(1-\frac{3}{2}e)P_2+\frac{16}{35}\pi w\frac{a^7}{r^5}e^2P_4,$$

$$U_i''=2\pi w a^2(1-\frac{2}{3}e-\frac{1}{5}e^2)-\frac{2}{3}\pi w r^2-\frac{8}{15}\pi w r^2(e+\frac{9}{14}e^2)P_2.$$

The external potential U_e of the spheroid is equal to $U_e'+U_e''$, and the internal potential U_i is equal to $U_i'+U_i''$. For application to the problem of the figure of the Earth the potential of rotation must be added, and if ω be the angular velocity of rotation, this potential is $\frac{1}{2}\omega^2r^2\sin^2\theta$ or $\frac{1}{3}\omega^2r^2(1-P_2)$.

Now let V_e, V_i be the external and internal potentials, inclusive of rotation, and we have

$$\left.\begin{aligned}V_e&=\frac{4}{3}\pi w\frac{a^3}{r}(1-e+\frac{2}{5}f)-\frac{8}{15}\pi w\frac{a^5}{r^3}(e-\frac{3}{2}e^2-\frac{1}{7}f)P_2\\&\qquad+\frac{16}{35}\pi w\frac{a^7}{r^5}(e^2-\frac{8}{9}f)P_4+\frac{1}{3}\omega^2r^2(1-P_2)\\V_i&=2\pi w a^2(1-\frac{2}{3}e-\frac{1}{5}e^2+\frac{4}{15}f)-\frac{2}{3}\pi w r^2\\&\qquad-\frac{8}{15}\pi w r^2(e+\frac{9}{14}e^2-\frac{1}{7}f)P_2-\frac{32}{315}\pi w\frac{r^4}{a^2}fP_4+\frac{1}{3}\omega^2r^2(1-P_2)\end{aligned}\right\}\quad(5)$$

The first term of V_i is independent of r, θ and is only inserted in order that V may be a continuous function at the surface of the spheroid.

It will be supposed hereafter that the heterogeneous Earth is built up of layers of density w, bounded externally and internally by spheroids defined by $a+\delta a$, $e+\delta e$, $f+\delta f$ and a, e, f. It is obvious that the potential of such a body may be written down from (5) by replacing each term by an integral.

If a, e, f denote the superficial values of a, e, f we shall have such integrals as

$$\int_0^a w\frac{d}{da}[a^5(e-\frac{3}{2}e^2-\frac{1}{7}f)]da \text{ and } \int_a^{\mathrm{a}} w\frac{d}{da}[e+\frac{9}{14}e^2-\frac{1}{7}f]da.$$

For the sake of brevity I shall write these

$$\int_0^a wd[a^5(e-\frac{3}{2}e^2-\frac{1}{7}f)] \text{ and } \int_a^{\mathrm{a}} wd[e+\frac{9}{14}e^2-\frac{1}{7}f].$$

It may be well to note here that for the heterogeneous Earth

$$\left.\begin{aligned}M&=\frac{4}{3}\pi\int_0^{\mathrm{a}} wd[a^3(1-e+\frac{2}{5}f)]\\C&=\frac{8}{15}\pi\int_0^{\mathrm{a}} wd[a^5(1-e+\frac{4}{7}f)]\\A&=\frac{8}{15}\pi\int_0^{\mathrm{a}} wd[a^5(1-2e+\frac{3}{2}e^2+\frac{5}{7}f)]\\C-A&=\frac{8}{15}\pi\int_0^{\mathrm{a}} wd[a^5(e-\frac{3}{2}e^2-\frac{1}{7}f)]\end{aligned}\right\}\quad . \; . \; . \quad(6)$$

§ 2. Heterogeneous Planet. The surfaces of equal density are level surfaces.

It will now be supposed that the substance of which the heterogeneous planet is formed is plastic enough to allow the surfaces of equal density to be level surfaces.

It is necessary to write down the potential of the planet at any internal point, and for this purpose I find it better to introduce a new parameter in place of the ellipticity e. This parameter is h, defined by

$$h=e-\tfrac{25}{14}e^2-\tfrac{1}{7}f \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

I do not quite understand why this substitution should lead to simplification, but I may remark that $h=e-2e^2-\frac{1}{7}(f-\frac{3}{2}e^2)$, and that $f-\frac{3}{2}e^2$ is the coefficient of $\sin^2\theta\cos^2\theta$ in the equation to the spheroid. Thus the existence of the fraction $\frac{25}{14}$ is in some sense explained.

It will be found that the equation (1) to the stratum a, in terms of this parameter, becomes

$$r=a\{1-\tfrac{1}{3}h-\tfrac{1}{2}\tfrac{167}{210}h^2+\tfrac{3}{35}f-\tfrac{2}{3}h(1+2h)P_2+\tfrac{8}{35}(\tfrac{3}{2}h^2-f)P_4\} \quad . \quad (8$$

Also

$$\left.\begin{aligned} C&=\tfrac{8}{15}\pi\int_0^a wd[a^5(1-h-\tfrac{25}{14}h^2+\tfrac{3}{7}f)] \\ C-A&=\tfrac{8}{15}\pi\int_0^a wd[a^5(h+\tfrac{2}{7}h^2)] \end{aligned}\right\} \quad . \quad . \quad (9)$$

Let us now for brevity write

$$\left.\begin{aligned} S_0&=\int_0^a wd[a^3(1-e+\tfrac{2}{5}f)] &&=\int_0^a wd[a^3(1-h-\tfrac{25}{14}h^2+\tfrac{9}{35}f)] \\ S_2&=\int_0^a wd[a^5(e-\tfrac{3}{2}e^2-\tfrac{1}{7}f)] &&=\int_0^a wd[a^5(h+\tfrac{2}{7}h^2)] \\ S_4&=\int_0^a wd[a^7(e^2-\tfrac{2}{9}f)] &&=\int_0^a wd[a^7(h^2-\tfrac{2}{9}f)] \\ T_2&=\int_a^a wd[e+\tfrac{9}{14}e^2-\tfrac{1}{7}f] &&=\int_a^a wd[h+\tfrac{17}{7}h^2] \\ T_4& &&=\int_a^a wd[\tfrac{f}{a^2}] \end{aligned}\right\} \quad (10)$$

The terms of the second order in S_0 are not required, so that, in fact, I take $S_0=\int_0^a wd[a^3(1-h)]$.

The formulæ (5) and (10) enable us to write down the potential at any internal point as follows :—

$$\frac{3V}{4\pi}=\frac{S_0}{r}-\tfrac{2}{5}\frac{S_2P_2}{r^3}+\tfrac{12}{35}\frac{S_4P_4}{r^5}-\tfrac{2}{5}r^2T_2P_2-\tfrac{8}{105}r^4T_4P_4+\frac{\omega^2}{4\pi}r^2(1-P_2)$$

$$. \quad . \quad . \quad . \quad (11)$$

If it be assumed that the equipotential surfaces are also surfaces of equal density, the equation $V=$ constant must be reducible to the form (8). Hence, if in (11) we attribute to r the value (8), the coefficients of P_2 and of P_4 must vanish. In effecting this substitution we attribute to r its full value in the term of the lowest order, namely S_0/r; in terms of the first order, namely those involving S_2, T_2, and ω^2, we may put $a(1-\frac{1}{3}h-\frac{2}{3}hP_2)$ for r; and in the terms of the second order, namely, those involving S_4 and T_4, we simply put a for r. A consideration of (11) shows that there are several functions of r, P_2, P_4, which will have to be evaluated, and it is obvious that the expressions in question, when developed to the required order, will involve $P_2{}^2$. But

$$P_2{}^2=\tfrac{1}{5}+\tfrac{2}{7}P_2+\tfrac{18}{35}P_4,$$

and it will be found by aid of this formula that, to the required order of approximation,

$$\left.\begin{aligned}
\frac{a}{r}&=1+\tfrac{1}{3}h+\tfrac{209}{210}h^2-\tfrac{3}{35}f+\tfrac{2}{3}h(1+\tfrac{20}{7}h)P_2+\tfrac{8}{35}(f-\tfrac{1}{2}h^2)P_4\\
\frac{a^3}{r^3}P_2&=\tfrac{3}{5}h+(1+\tfrac{11}{7}h)P_2-\tfrac{24}{35}hP_4\\
\frac{r^2}{a^2}P_2&=-\tfrac{4}{15}h+(1-\tfrac{22}{21}h)P_2-\tfrac{24}{35}hP_4\\
\frac{r^2}{a^2}(1-P_2)&=1-\tfrac{2}{3}h-(1+\tfrac{2}{7}h)P_2+\tfrac{24}{35}hP_4
\end{aligned}\right\}\quad(12)$$

By aid of (12) it may be shown that the conditions that the level surfaces shall be surfaces of equal density are

$$\frac{S_0}{a}(h+\tfrac{20}{7}h^2)-\tfrac{3}{5}\frac{S_2}{a^3}(1+\tfrac{11}{7}h)-\tfrac{3}{5}a^2T_2(1-\tfrac{22}{21}h)-\frac{3\omega^2}{8\pi}a^2(1+\tfrac{2}{7}h)=0 \quad . \quad . \quad (13)$$

$$\frac{S_0}{a}(f-\tfrac{1}{2}h^2)-\tfrac{3}{5}\frac{S_2}{a^3}h+\tfrac{3}{2}\frac{S_4}{a^5}+\tfrac{6}{5}a^2T_2h-\tfrac{1}{3}a^4T_4+\frac{3\omega^2}{4\pi}a^2h=0 \quad . \quad . \quad (14)$$

Since ω^2a^3/S_0 is a quantity of the same order as h, (13) involves terms of two orders, but (14) consists entirely of terms of the second order.

If the terms of the second order be omitted, (13) becomes

$$\frac{S_0}{a}h-\tfrac{3}{5}\frac{S_2}{a^3}-\tfrac{3}{5}a^2T_2-\frac{3\omega^2a^2}{8\pi}=0 \quad . \quad . \quad . \quad . \quad . \quad (15)$$

This may be used for the elimination of T_2 and of ω^2 from (14); for multiplying it by $2h$ and adding it to (14) we have

$$\frac{S_0}{a}(f+\tfrac{3}{2}h^2)-3\frac{S_2}{a^3}h+\tfrac{3}{2}\frac{S_4}{a^5}-\tfrac{1}{3}a^4T_4=0 \quad . \quad . \quad . \quad . \quad . \quad (16)$$

The conditions for the identity of the two surfaces are then (13) and (16).

In order to obtain the differential equations to be satisfied by h and f, it is necessary to eliminate the S and T integrals by differentiation, and the results may be much simplified by the use of the approximate form (15) of (13), and of its derivatives.

Our first task is, then, to pursue the approximate equation (15).

The equation (15) may be written in the form

$$\frac{S_0}{a^3}h-\frac{3}{5}\frac{S_2}{a^5}-\frac{3}{5}T_2-\frac{3\omega^2}{8\pi}=0.$$

To the same degree of approximation we have $S_0=3\int_0^a wa^2da$, so that $\frac{dS_0}{da}=S_0'=3wa^2$. It follows, therefore, that

$$w=\frac{1}{3}\frac{S_0'}{a^2}. \quad \ldots \ldots \ldots \quad (17)$$

On differentiating our equation and using (17) we find

$$S_2=S_0a^3\left(\frac{h}{a}-\frac{1}{3}\frac{dh}{da}\right). \quad \ldots \ldots \ldots \quad (18)$$

Differentiating again, and effecting some reductions, we have

$$S_0\frac{d^2h}{da^2}=\frac{6S_0}{a^2}h-2S_0'\left(\frac{dh}{da}+\frac{h}{a}\right). \quad \ldots \ldots \ldots \quad (19)$$

It would be easy, by means of (18), to eliminate S_2 from the terms of the second order in (13), but I prefer to postpone that elimination for the present; we can, however, at once eliminate it from (16). Effecting this elimination, and repeating (13), our conditions are

$$\frac{S_0}{a}\left(h+\frac{20}{7}h^2\right)-\frac{3}{5}\frac{S_2}{a^3}\left(1+\frac{11}{7}h\right)-\frac{3}{5}a^2T_2\left(1-\frac{32}{21}h\right)-\frac{3\omega^2}{8\pi}a^2\left(1+\frac{2}{7}h\right)=0$$

$$\frac{S_0}{a^5}\left(f-\frac{3}{2}h^2+ah\frac{dh}{da}\right)+\frac{3}{2}\frac{S_4}{a^9}-\frac{1}{3}T_4=0 \quad \ldots \quad (20)$$

The equation (19) has not been used yet, but it will prove useful hereafter.

§ 3. *The Differential Equation for f.*

By differentiating the second of (20) and using (17) and (19), I find

$$S_0a^5\left(\frac{df}{da}-5\frac{f}{a}+\frac{27}{2}\frac{h^2}{a}-7h\frac{dh}{da}+a\left(\frac{dh}{da}\right)^2\right)-\frac{27}{2}S_4=0 \quad \ldots \quad (21)$$

Differentiating again, and again using (17) and (19), I find

$$S_0 a^5\Big(\frac{d^2f}{da^2}-20\frac{f}{a^2}+12\frac{h^2}{a^2}+4\frac{hdh}{ada}-\Big(\frac{dh}{da}\Big)^2\Big)$$

$$+S_0'a^6 2\Big(\frac{df}{ada}+\frac{2f}{a^2}-4\frac{h^2}{a^2}-6\frac{hdh}{ada}-3\Big(\frac{dh}{da}\Big)^2\Big)=0 . \quad . \quad . \quad (22)$$

I now introduce a new symbol w_0, which is to denote the mean density of all the matter lying inside the spheroid defined by a; then

$$S_0=\int_0^a wda^3=w_0a^3$$

$$S_0'=3wa^2.$$

Thus $\dfrac{S_0'}{S_0}=\dfrac{3}{a}\dfrac{w}{w_0}$.

In obtaining this result the ellipticity of the spheroid has been neglected, but for the present this approximation suffices, and (22) is then easily reducible to the form

$$\frac{d^2f}{da^2}+6\frac{w}{w_0}\frac{df}{ada}-\Big(20-6\frac{w}{w_0}\Big)\frac{f}{a^2}+12\Big(1-\frac{w}{w_0}\Big)\frac{h^2}{a^2}+\Big(4-18\frac{w}{w_0}\Big)\frac{hdh}{ada}$$

$$-\Big(1+9\frac{w}{w_0}\Big)\Big(\frac{dh}{da}\Big)^2=0 \quad . \quad (23)$$

This is the differential equation for f, and I shall in § 9 solve it on the assumption of a certain law of internal density of the Earth.

§4. *The Differential Equation for h.*

I now return to the first of (20), and divide it by $a^2(1-\frac{22}{21}h)$, so that it becomes

$$\frac{S_0}{a^3}\big(h+\tfrac{82}{21}h^2\big)-\tfrac{3}{5}\frac{S_2}{a^5}\big(1+\tfrac{55}{21}h\big)-\tfrac{3}{5}T_2-\frac{3\omega^2}{8\pi}\big(1+\tfrac{4}{3}h\big)=0 \quad . \quad (24)$$

As a preliminary to the differentiation which will eliminate the T_2 integral I indicate certain transformations.

We have $$S_0=\int_0^a wd[a^3(1-h)]$$

$$S_0'=3wa^2\Big(1-h-\tfrac{1}{3}a\frac{dh}{da}\Big).$$

Hence $$w=\frac{S_0'}{3a^2}\Big(1+h+\tfrac{1}{3}a\frac{dh}{da}\Big) \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

If S_2, T_2 as defined in (10) be differentiated, and if the value of w as given in (25) be used, it will be found that

$$3\frac{dS_2}{da}=\frac{S_0'}{a^2}\left(5h+a\frac{dh}{da}+\tfrac{45}{7}h^2+\tfrac{68}{21}ah\frac{dh}{da}+\tfrac{1}{3}\left(a\frac{dh}{da}\right)^2\right)$$

and

$$\left.\begin{aligned}3\left(1+\tfrac{55}{21}h\right)\frac{dS_2}{da}&=\frac{S_0'}{a^2}\left(5h+a\frac{dh}{da}+\tfrac{410}{21}h^2+\tfrac{41}{7}ah\frac{dh}{da}+\tfrac{1}{3}\left(a\frac{dh}{da}\right)^2\right)\\ 3\frac{dT_2}{da}&=-\frac{S_0'}{a^2}\left(\frac{dh}{da}+\tfrac{41}{7}h\frac{dh}{da}+\tfrac{1}{3}a\left(\frac{dh}{da}\right)^2\right)\end{aligned}\right\}\quad(26)$$

On differentiating (24) and using (26) and (18) it will be found that

$$S_2+S_0a^3\left(-\frac{h}{a}+\tfrac{1}{3}\frac{dh}{da}-\tfrac{9}{7}\frac{h^2}{a}+\tfrac{76}{63}h\frac{dh}{da}+\tfrac{11}{63}a\left(\frac{dh}{da}\right)^2\right)-\frac{\omega^2a^6}{6\pi}\frac{dh}{da}=0.\quad(27)$$

On differentiating (27) and again using (26) and (19) in the small terms it will be found that

$$S_0\left(\frac{d^2h}{da^2}-6\frac{h}{a^2}+14\frac{h^2}{a^2}+\tfrac{68}{7}\frac{hdh}{ada}+\tfrac{40}{7}\left(\frac{dh}{da}\right)^2\right)$$

$$+S_0'\left(2\frac{dh}{da}+2\frac{h}{a}-\tfrac{14}{3}\frac{h^2}{a}-\tfrac{52}{21}ah\frac{dh}{da}-\tfrac{76}{21}a\left(\frac{dh}{da}\right)^2\right)$$

$$-\frac{3\omega^2a^2}{\pi S_0}\left(S_0-\tfrac{1}{3}S_0'a\right)\left(\frac{h}{a}+\frac{dh}{da}\right)=0.\quad(28)$$

Since $S_0=w_0a^3(1-h)$, it follows from (25) that

$$\frac{S_0'}{S_0}=\frac{3}{a}\frac{w}{w_0}\left(1-\tfrac{1}{3}a\frac{dh}{da}\right)\;.\;.\;.\;.\;.\;.\quad(29)$$

I shall later denote by m the ratio of equatorial centrifugal force to equatorial gravity, and by an extension of this notation I will now write

$$m=\frac{\omega^2a^3}{\frac{4}{3}\pi S_0}\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\quad(30)$$

By means of (29) and (30) equation (28) becomes

$$\frac{d^2h}{da^2}+6\frac{w}{w_0}\frac{dh}{ada}-\left(1-\frac{w}{w_0}\right)\left[6\frac{h}{a^2}-14\frac{h^2}{a^2}-\tfrac{68}{7}\frac{hdh}{ada}-\tfrac{40}{7}\left(\frac{dh}{da}\right)^2\right.$$

$$\left.+4m\left(\frac{h}{a^2}+\frac{dh}{ada}\right)\right]=0\quad.\quad(31)$$

This is the differential equation to be satisfied by h. If the terms of the second order be omitted it is the equation for the

ellipticity of internal strata as given in any treatise on the theory of the figure of the Earth.

The transformation by which h was substituted for e has enabled us to obtain an equation for h in which f is not involved. Moreover h has been chosen as such a function of e that all the latter terms are multiplied by the simple factor $1-w/w_0$, instead of by various more complex functions of the density, as was the case in the differential equation for f.

§ 5. *Radau's form of the Differential Equation of the Ellipticity.*

I shall now include the terms of the second order in M. Radau's very remarkable transformation of the equation of the last section.

Since $$w_0 a^3(1-h)=\int_0^a w\,d[a^3(1-h)],$$

it follows that

$$\frac{w}{w_0}=1+\tfrac{1}{3}\left(1+\tfrac{1}{3}a\frac{dh}{da}\right)\frac{adw_0}{w_0da}. \qquad (32)$$

The equation (31) may therefore be written

$$\frac{d^2h}{da^2}+6\frac{dh}{ada}+2\frac{adw_0}{w_0da}\left(\frac{dh}{ada}+\frac{h}{a^2}\right)$$
$$-\tfrac{1}{3}\frac{adw_0}{w_0da}\left\{14\frac{h^2}{a^2}+\tfrac{52}{7}\frac{hdh}{ada}+\tfrac{26}{7}\left(\frac{dh}{da}\right)^2-4m\left(\frac{dh}{ada}+\frac{h}{a^2}\right)\right\}=0.$$

The last term here includes all the terms of the second order.

If we write $$\eta=\frac{adh}{hda},$$

$$\frac{d^2h}{da^2}=\frac{h}{a^2}\left(a\frac{d\eta}{da}-\eta+\eta^2\right), \qquad \frac{dh}{ada}=\frac{h}{a^2}\eta.$$

Thus the equation becomes

$$a\frac{d\eta}{da}+5\eta+\eta^2+2\frac{adw_0}{w_0da}(1+\eta)$$
$$-\tfrac{4}{21}\frac{adw_0}{w_0da}h\left\{18+\tfrac{13}{2}(1+\eta)^2-7\frac{m}{h}(1+\eta)\right\}=0.$$

Now it is easy to prove that

$$a\frac{d\eta}{da}=\frac{2\sqrt{(1+\eta)}}{w_0a^4}\frac{d}{da}\left[w_0a^5\sqrt{(1+\eta)}\right]-2\left(5+\frac{adw_0}{w_0da}\right)(1+\eta).$$

Therefore the equation may be written

$$\frac{2\sqrt{(1+\eta)}}{w_0 a^4}\frac{d}{da}[w_0 a^5\sqrt{(1+\eta)}] = 10(1+\tfrac{1}{2}\eta-\tfrac{1}{10}\eta^2)$$
$$+\tfrac{4}{21}\frac{a\,dw_0}{w_0\,da}h\{18+\tfrac{13}{2}(1+\eta)^2-7\frac{m}{h}(1+\eta)\}.$$

In the terms of the second order we may put $\dfrac{a\,dw_0}{w_0\,da}$ equal to $-3(1-\dfrac{w}{w_0})$; therefore

$$\frac{d}{da}[w_0 a^5\sqrt{(1+\eta)}] = \frac{5w_0 a^4}{\sqrt{(1+\eta)}}\{1+\tfrac{1}{2}\eta-\tfrac{1}{10}\eta^2$$
$$-\tfrac{2}{35}h(1-\frac{w}{w_0})[18+\tfrac{13}{2}(1+\eta)^2-7\frac{m}{h}(1+\eta)]\} \quad . \quad (33)$$

This is M. Radau's equation, with the inclusion of the terms of the second order. These terms have been determined by M. Callandreau, but the form in which he gives them appears to me more complicated than the above.

Let us consider the function within { } on the right-hand side of the equation (33), and in the first place omitting the terms of the second order consider the function $\dfrac{(1+\frac{1}{2}\eta-\frac{1}{10}\eta^2)}{\sqrt{(1+\eta)}}$. It is equal to unity when η is zero, rises to a maximum of 1·00074 when $\eta=\frac{1}{3}$, and only falls to ·8 when $\eta=3$. Now it has been proved that η is necessarily less than 3, and is positive.* In all the cases which are likely to prove of practical interest η is very much less than 3. In the case of the Earth, for example, η is equal to about ·56 at the surface, and vanishes at the centre. Now when $\eta=·56$ this function is equal to ·99971. Therefore between the centre and the surface it rises from unity to 1·00074 and then falls to ·99971. It is obvious that any kind of average value of the function, estimated over the range from centre to surface, can at most differ from unity in the fourth place of decimals. When the terms of the second order are included I think the average value is yet nearer unity than when they are omitted, for in such a case as that of the Earth $(1+\frac{1}{2}\eta-\frac{1}{10}\eta^2)\div\sqrt{(1+\eta)}$ is greater than unity throughout the greater part of its range, and, although I cannot prove it absolutely, I believe that $18+\frac{13}{2}(1+\eta)^2-7\frac{m}{h}(1+\eta)$ or $18-\frac{49}{26}\frac{m^2}{h^2}+\frac{13}{2}(1+\eta-\frac{7}{13}\frac{m}{h})^2$ is always positive. If this is the case the whole function is on the average nearer unity than when the terms of the second order are omitted.

* Professor Helmert tells me that he doubts the universal validity of the proof of this. I have to thank him for valuable information given me while writing this paper.

Supposing, then, that $1+\lambda$ denotes a proper mean value of the function

$$\left\{1+\tfrac{1}{2}\eta-\tfrac{1}{10}\eta^2-\tfrac{2}{35}h\left(1-\frac{w}{w_0}\right)\left[18+\tfrac{13}{2}(1+\eta)^2-7\frac{m}{h}(1+\eta)\right]\right\}(1+\eta)^{-\frac{1}{6}},$$

estimated over the whole range from centre to surface, we must have

$$\mathrm{w}_0\mathrm{a}^5\sqrt{(1+\eta_1)}=5(1+\lambda)\int_0^{\mathrm{a}}w_0a^4da \quad . \quad . \quad . \quad . \quad (34)$$

where w_0, a, η_1 denote the superficial values of those quantities; and we may feel sure that $1+\lambda$ will not differ from unity until we come to at least the fourth place of decimals.

I shall in § 12 attempt to use this remarkable result for evaluating the ellipticity of the Earth's surface from the Precessional Constant.

§ 6. *Gravity at the Earth's Surface.*

In order to render this presentation of the theory of the Earth's figure more complete I shall now go on to find the theoretical expression for gravity, although the same investigation is to be found in various other places.

At the surface of the planet the integrals T_2, T_4 vanish, and the potential (11) becomes

$$3\frac{V}{4\pi}=\frac{S_0}{r}-\tfrac{3}{5}\frac{S_2P_2}{r^3}+\tfrac{12}{35}\frac{S_4P_4}{r^5}+\frac{\omega^2r^2}{4\pi}(1-P_2).$$

In this section, as elsewhere, the superficial values of the various quantities are denoted by Roman in place of Italic type.

Through the vanishing of T_2, T_4 the equations (20), which denote that the surface is a level surface, become

$$\frac{\mathrm{S}_0}{\mathrm{a}}(\mathrm{h}+\tfrac{2}{7}\mathrm{h}^2)-\tfrac{3}{5}\frac{\mathrm{S}_2}{\mathrm{a}^3}(1+\tfrac{1}{7}\mathrm{h})-\frac{3\omega^2}{8\pi}\mathrm{a}^2(1+\tfrac{2}{7}\mathrm{h})=0$$

$$\frac{\mathrm{S}_0}{\mathrm{a}}(\mathrm{f}+\tfrac{3}{2}\mathrm{h}^2)-3\frac{\mathrm{S}_2}{\mathrm{a}^3}\mathrm{h}+\tfrac{3}{2}\frac{\mathrm{S}_4}{\mathrm{a}^5}=0$$

It must be observed that the mass M of the spheroid is equal to $\frac{4}{3}\pi\mathrm{S}_0$; and we deduce

$$\left.\begin{aligned}\mathrm{S}_2&=\frac{5\mathrm{Ma}^2}{4\pi}\left\{\mathrm{h}+\tfrac{9}{7}\mathrm{h}^2-\tfrac{1}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}(1-\tfrac{9}{7}\mathrm{h})\right\}\\ \mathrm{S}_4&=\frac{\mathrm{Ma}^4}{2\pi}\left\{\tfrac{7}{2}\mathrm{h}^2-\mathrm{f}-\tfrac{5}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}\mathrm{h}\right\}\end{aligned}\right\} \quad . \quad . \quad . \quad (35)$$

The potential may therefore be written

$$V=\mathrm{M}\Big[\frac{1}{r}-\frac{2}{3}\frac{\mathrm{a}^2}{r^3}\{\mathrm{h}+\tfrac{9}{7}\mathrm{h}^2-\tfrac{1}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}(1-\tfrac{9}{7}\mathrm{h})\}P_2$$

$$+\frac{8}{35}\frac{\mathrm{a}^4}{r^5}\{\tfrac{7}{2}\mathrm{h}^2-\mathrm{f}-\tfrac{5}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}\mathrm{h}\}P_4+\frac{1}{3}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}\frac{r^2}{\mathrm{a}^3}(1-P_2)\Big].$$

At the equator $r=\mathrm{a}$, $P_2=-\frac{1}{2}$, $P_4=\frac{3}{8}$, and equatorial gravity, say g_e, is equal to $-dV/dr$.
It is easy then by differentiation to show that

$$g_e=\frac{\mathrm{M}}{\mathrm{a}^2}[1+\mathrm{h}+\tfrac{39}{14}\mathrm{h}^2-\tfrac{3}{7}\mathrm{f}-\tfrac{3}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}(1+\tfrac{2}{7}\mathrm{h})] \quad . \quad . \quad (36)$$

Now let m denote the ratio of equatorial centrifugal force to equatorial gravity, so that

$$\mathrm{m}=\frac{\omega^2\mathrm{a}}{g_e}$$

It follows that

$$\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}=\mathrm{m}[1+\mathrm{h}+\tfrac{39}{14}\mathrm{h}^2-\tfrac{3}{7}\mathrm{f}-\tfrac{3}{2}\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}(1+\tfrac{2}{7}\mathrm{h})]$$

$$=\mathrm{m}[1+\mathrm{h}-\tfrac{3}{2}\mathrm{m}+\tfrac{39}{14}\mathrm{h}^2-\tfrac{27}{14}\mathrm{mh}+\tfrac{9}{4}\mathrm{m}^2-\tfrac{3}{7}\mathrm{f}] \quad . \quad . \quad (36)$$

The function which naturally arises in the consideration of figures of equilibrium of rotating fluid is the ratio of ω^2 to the density. But

$$\mathrm{M}=\tfrac{4}{3}\pi\mathrm{w}_0\mathrm{a}^3(1-\mathrm{h}-\tfrac{25}{14}\mathrm{h}^2+\tfrac{9}{35}\mathrm{f})\ ;$$

hence

$$\frac{3\,\omega^2}{4\pi\mathrm{w}_0}=\mathrm{m}[1-\tfrac{3}{2}\mathrm{m}+\tfrac{9}{4}\mathrm{m}^2-\tfrac{3}{7}\mathrm{mh}-\tfrac{6}{35}\mathrm{f}].$$

If m were an ideally perfect parameter in which to express our results, h and f should have entirely disappeared from this equatioh, since m should only depend on ω^2 and w_0, and should be perfectly independent of the figure of the planet.
However, for our present purpose it suffices to take

$$\frac{\omega^2\mathrm{a}^3}{\mathrm{M}}=\mathrm{m}(1+\mathrm{h}-\tfrac{3}{2}\mathrm{m}),\ \text{or}\ \frac{3\omega^2}{4\pi\mathrm{w}_0}=\mathrm{m}(1-\tfrac{3}{2}\mathrm{m}) \quad . \quad . \quad (36)$$

To this order there is no objection to the use of m, and I bow to custom in continuing to use it.
The potential of the planet may now be written

$$V=\mathrm{M}\Big[\frac{1}{r}-\frac{2}{3}\frac{\mathrm{a}^2}{r^3}(\mathrm{h}-\tfrac{1}{2}\mathrm{m}+\tfrac{9}{7}\mathrm{h}^2+\tfrac{1}{7}\mathrm{mh}+\tfrac{3}{4}\mathrm{m}^2)P_2$$

$$+\frac{8}{35}\frac{\mathrm{a}^4}{r^5}(\tfrac{7}{2}\mathrm{h}^2-\tfrac{5}{2}\mathrm{mh}-\mathrm{f})P_4+\tfrac{1}{3}\mathrm{m}(1+\mathrm{h}-\tfrac{3}{2}\mathrm{m})\frac{r^2}{\mathrm{a}^3}(1-P_2)\Big] \quad (37)$$

It will perhaps be more convenient here to reintroduce the ellipticity instead of h. I observe, then, that $\mathrm{h}+\frac{9}{7}\mathrm{h}^2$ is equal to $\mathrm{e}-\frac{1}{2}\mathrm{e}^2-\frac{1}{7}\mathrm{f}$, and that throughout the rest of the expression e may be written for h.

The quantity $\mathfrak{d}$ used by Dr. Helmert in his *Geodesy* (vol. ii. pp. 77–85) is the same as my $\frac{7}{2}\mathrm{e}^2-\frac{5}{2}\mathrm{me}-\mathrm{f}$, and my results will be found to agree with his.

We have, then,

$$\left.\begin{aligned} V=\mathrm{M}\Big[\frac{1}{r}-\frac{2}{3}\frac{\mathrm{a}^2}{r^3}&(\mathrm{e}-\tfrac{1}{2}\mathrm{m}-\tfrac{1}{2}\mathrm{e}^2+\tfrac{1}{7}\mathrm{me}+\tfrac{3}{4}\mathrm{m}^2-\tfrac{1}{7}\mathrm{f})P_2 \\ &+\tfrac{8}{35}\frac{\mathrm{a}^4}{r^5}(\tfrac{7}{2}\mathrm{e}^2-\tfrac{5}{2}\mathrm{me}-\mathrm{f})P_4+\tfrac{1}{3}\mathrm{m}(1+\mathrm{e}-\tfrac{3}{2}\mathrm{m})\frac{r^2}{\mathrm{a}^3}(1-P_2)\Big] \\ g_e=\frac{\mathrm{M}}{\mathrm{a}^2}[1+\mathrm{e}-\tfrac{3}{2}\mathrm{m}&+\mathrm{e}^2-\tfrac{27}{14}\mathrm{me}+\tfrac{9}{4}\mathrm{m}^2-\tfrac{4}{7}\mathrm{f}] \end{aligned}\right\}. \quad (38)$$

Clairaut's ratio is that of the excess of polar above equatorial gravity to equatorial gravity. I follow Dr. Helmert in denoting this ratio by $\mathfrak{b}$; so that

$$\mathfrak{b}=\frac{g_p-g_e}{g_e}.$$

At the pole $r=\mathrm{a}(1-\mathrm{e})$, $P_2=P_4=1$. If $-dV/dr$ be found and these values introduced, we get

$$g_p=\frac{\mathrm{M}}{\mathrm{a}^2}(1+\mathrm{m}+\tfrac{6}{7}\mathrm{me}-\tfrac{3}{2}\mathrm{m}^2-\tfrac{9}{7}\mathrm{f}).$$

Then $\quad g_p-g_e=\dfrac{\mathrm{M}}{\mathrm{a}^2}(\tfrac{5}{2}\mathrm{m}-\mathrm{e}-\mathrm{e}^2+\tfrac{39}{14}\mathrm{me}-\tfrac{15}{4}\mathrm{m}^2-\tfrac{5}{7}\mathrm{f})$;

and since to the first order $g_e=\dfrac{\mathrm{M}}{\mathrm{a}^2}(1+\mathrm{e}-\tfrac{3}{2}\mathrm{m})$, we have

$$\mathfrak{b}=\tfrac{5}{2}\mathrm{m}-\mathrm{e}-\tfrac{17}{14}\mathrm{me}-\tfrac{5}{7}\mathrm{f}. \quad . \quad . \quad . \quad . \quad (39)$$

The form of the potential shows that the general expression for gravity must be

$$g=g_e[1+\mathfrak{b}\cos^2\theta+a\sin^2\theta\cos^2\theta],$$

where it remains to determine a.

This may be written

$$g=g_e[1+\tfrac{1}{3}\mathfrak{b}+\tfrac{2}{15}a+(\tfrac{2}{3}\mathfrak{b}+\tfrac{2}{21}a)P_2-\tfrac{8}{35}aP_4].$$

The value of a is then determinable by finding the coefficient of P_4 in the expression for g.

Now $g^2 = \left(\frac{dV}{dr}\right)^2 + \left(\frac{dV}{rd\theta}\right)^2$, where after differentiation the value (1) is attributed to r.

Suppose that $-\frac{dV}{dr} = \frac{\mathrm{M}}{\mathrm{a}^2}[G_0 + G_1 + G_2]$, $\frac{dV}{rd\theta} = \frac{\mathrm{M}}{\mathrm{a}^2} H_1$, where the suffixes denote the orders of the several terms; then it is easy to prove that $g = \frac{\mathrm{M}}{\mathrm{a}^2}[G_0 + G_1 + G_2 + \frac{1}{2}\frac{H_1^2}{G_0}]$.

Since G_0 is equal to unity as far as the order zero,

$$g = -\frac{dV}{dr} + \frac{\mathrm{M}}{\mathrm{a}^2}(\tfrac{1}{2}H_1^2).$$

In order to find H_1 the terms of the second order in (38) are to be dropped, and we find

$$\frac{dV}{rd\theta} = \frac{\mathrm{M}}{\mathrm{a}^2}.2\mathrm{e} \sin\theta \cos\theta.$$

Therefore $\qquad H_1 = 2e \sin\theta \cos\theta,$

and $\qquad \tfrac{1}{2}H_1^2 = 2\mathrm{e}^2 \sin^2\theta \cos^2\theta$

$$= 2\mathrm{e}^2(\tfrac{2}{15} + \tfrac{2}{21}P_2 - \tfrac{8}{35}P_4).$$

We are only concerned with the term in P_4, and this portion of the transverse component of gravity is $-\frac{16}{35}\frac{\mathrm{M}}{\mathrm{a}_2}\mathrm{e}^2 P_4$.

It is next required to find the term in P_4 in $-\frac{dV}{dr}$. After the differentiation of V we shall require to determine the term in P_4 in the following functions, namely, $\frac{\mathrm{a}^2}{r^2}$, $\frac{\mathrm{a}^4}{r^4}P_2$, $\frac{\mathrm{a}^6}{r^6}P_4$, $\frac{r}{\mathrm{a}}(1 - P_2)$.

Now $\frac{\mathrm{a}^2}{r^2} = -\frac{18}{35}(\frac{3}{2}\mathrm{e}^2 - \mathrm{f})P_4 + 3(\frac{2}{3}\mathrm{e})^2 P_2^2 + \ldots \quad = \frac{16}{35}\mathrm{f}P_4 + \ldots$

$\frac{\mathrm{a}^4}{r^4}P_2 = \frac{8}{3}\mathrm{e}P_2^2 + \ldots = \frac{8}{3}\mathrm{e}.\frac{18}{35}P_4 + \ldots \quad = \frac{48}{35}\mathrm{e}P_4 + \ldots$

$\frac{\mathrm{a}^6}{r^6}P_4 \quad = P_4$

$\frac{r}{\mathrm{a}}(1 - P_2) = \frac{2}{3}\mathrm{e}P_2^2 + \ldots = \frac{2}{3}\mathrm{e}.\frac{18}{35}P_4 + \ldots = \frac{12}{35}\mathrm{e}P_4 + \ldots$

It follows that the term in P_4 in $-dV/dr$ has a coefficient

$$\frac{\mathrm{M}}{\mathrm{a}^2}[\tfrac{16}{35}\mathrm{f} - 2(\mathrm{e} - \tfrac{1}{2}\mathrm{m})\tfrac{48}{35}\mathrm{e} + \tfrac{8}{7}(\tfrac{7}{2}\mathrm{e}^2 - \tfrac{5}{2}\mathrm{me} - \mathrm{f}) - \tfrac{2}{3}\mathrm{m}.\tfrac{12}{35}\mathrm{e}].$$

The term is therefore

$$-\tfrac{8}{35}\frac{M}{a^2}(3f-\tfrac{11}{2}e^2+\tfrac{15}{2}me)P_4.$$

Then adding the transverse component, it appears that the whole term is

$$-\tfrac{8}{35}\frac{M}{a^2}(3f-\tfrac{7}{2}e^2+\tfrac{15}{2}me)P_4.$$

But the coefficient of P_4 was shown to be $-\tfrac{8}{35}g_e a$; and since $g_e=M/a^2$ to the order zero, the coefficient in the expression for g is given by

$$a=3f-\tfrac{7}{2}e^2+\tfrac{15}{2}me.$$

In the expression for gravity the geocentric colatitude θ is used, and it remains to introduce the true colatitude λ, which is connected with θ by the formulæ

$$\theta=\lambda+2e\sin\lambda\cos\lambda,$$

and $$\cos^2\theta=\cos^2\lambda-4e\sin^2\lambda\cos^2\lambda.$$

Thus finally

$$\left.\begin{aligned} &g=g_e[1+\mathfrak{b}\cos^2\lambda-(\tfrac{5}{2}me-\tfrac{1}{2}e^2-3f)\sin^2\lambda\cos^2\lambda] \\ \text{where }\; &g_e=\frac{M}{a^2}[1+e-\tfrac{3}{2}m+e^2-\tfrac{27}{14}me+\tfrac{9}{4}m^2-\tfrac{4}{7}f] \\ &\mathfrak{b}=\tfrac{5}{2}m-e-\tfrac{17}{14}me-\tfrac{2}{7}f. \end{aligned}\right\} \quad . \quad . \quad (40)$$

I shall show in § 9 that f is probably about $-\cdot00000205$; m is $\frac{1}{288\cdot41}$, or $\cdot0034672$, and if e be taken as $\frac{1}{298}$

$$\tfrac{5}{2}me-\tfrac{1}{2}e^2-3f=\cdot0000295.$$

Thus $$g=g_e\{1+\mathfrak{b}\cos^2\lambda-\cdot0000295\sin^2\lambda\cos^2\lambda\} \quad . \quad . \quad (41)$$

The results of the pendulum experiments which have been made up to the present time are hardly sufficiently numerous or concordant amongst themselves to make it worth while to take into account this small term. If it represented a detectable inequality in gravity the residuals given on page 240 of volume ii. of Helmert's *Geodesy* would vary more or less as the square of the sine of twice the latitude; but they are quite irregular, being as follows :—

Latitude.	Residuals.	Latitude.	Residuals.
5°	$-\cdot0000139$	45°	$-\cdot0000015$
15	$-$ 054	55	$-$ 73
25	$+$ 246	65	$-$ 62
35	$+$ 008	75	$+$ 40

A great mass of material now awaits reduction, and we shall no doubt soon have from Dr. Helmert far more accurate results for gravity and for the ellipticity of the Earth's figure than any that have been obtained up to the present time.

§ 7. *The superficial values of the rates of increase of h and f.*

The rates of increase of *h* and *f* are given in (27) and (21); whence

$$\frac{adh}{da}-3h-\frac{27}{7}h^2+\frac{76}{21}h\left(\frac{adh}{da}\right))+\frac{11}{21}\left(\frac{adh}{da}\right)^2-\frac{\omega^2a^3}{2\pi S_0}\left(\frac{adh}{da}\right)+\frac{S_2}{S_0a^2}=0$$

$$\frac{adf}{da}-5f+\frac{27}{2}h^2-7h\left(\frac{adh}{da}\right)+\left(\frac{adh}{da}\right)^2-\frac{27}{2}\frac{S_4}{S_0a^4}=0.$$

But
$$S_0=\frac{3}{4\pi}M,$$
$$S_2=\frac{5Ma^2}{4\pi}\left[h+\frac{9}{7}h^2-\frac{1}{2}\frac{\omega^2a^3}{M}\left(1-\frac{2}{7}h\right)\right],$$
$$S_4=\frac{Ma^4}{2\pi}\left[\frac{7}{2}h^2-f-\frac{5}{2}\frac{\omega^2a^3}{M}h\right].$$

Whence

$$\frac{adh}{da}+2h+\frac{18}{7}h^2+\frac{76}{21}h\left(\frac{adh}{da}\right)+\frac{11}{21}\left(\frac{adh}{da}\right)^2-\frac{5}{2}\frac{\omega^2a^3}{M}\left(1-\frac{2}{7}h+\frac{4}{15}\frac{adh}{da}\right)=0$$

$$\frac{adf}{da}+4f-18h^2-7h\left(\frac{adh}{da}\right)+\left(\frac{adh}{da}\right)^2+\frac{45}{2}\frac{\omega^2a^3}{M}h=0.$$

But $\frac{\omega^2a^3}{M}=m(1-h-\frac{3}{2}m)$, so that the last term of the first of these equations may be written $-\frac{5}{2}m(1-\frac{9}{7}h-\frac{3}{2}m+\frac{4}{15}\frac{adh}{da})$, and the last term of the second is $+\frac{45}{2}mh$. The first equation then shows that to the first order $\frac{adh}{da}=\frac{5}{2}m-2h$. If this be used to eliminate dh/da from the terms of the second order in the first equation, and completely from the second, we get

$$\left.\begin{aligned}\frac{adh}{da}&=\frac{5}{2}m-2h+\frac{18}{7}h^2-\frac{41}{7}mh-\frac{75}{14}m^2\\ \frac{adf}{da}&=-4f+5mh-\frac{25}{4}m^2.\end{aligned}\right\} \quad . \quad . \quad (42)$$

The second of these may be combined with the first in the simple form

$$\frac{ad}{da}\left(f+\frac{5}{2}mh\right)+4f=0.$$

The parameter h denotes $e-\frac{25}{14}e^2-\frac{1}{7}f$; whence it may be shown that

$$\frac{ade}{da}=\frac{5}{2}\mathrm{m}-2\mathrm{e}-\mathrm{e}^2+\frac{53}{14}\mathrm{me}-\frac{25}{4}\mathrm{m}^2-\frac{2}{7}\mathrm{f}.$$

§ 8. *The Figure of a Homogeneous Mass with a small Nucleus.*

In order to obtain a preliminary estimate of the magnitude of f in the case of the Earth I shall first consider the case of a homogeneous mass with a nucleus at the centre of finite mass, but of infinitely small linear dimensions.

If we suppose the mass of the nucleus to be μ times that of the fluid, and that the form of surface is defined by the parameters a, h, f, it is clear from (10) and (11) that the external potential of the whole is

$$V=\frac{4}{3}\pi w\frac{a^3}{r}(1+\mu)-\frac{8}{15}\pi w\frac{a^5}{r^3}(h+\frac{2}{7}h^2)P_2+\frac{16}{35}\pi w\frac{a^7}{r^5}(h^2-\frac{3}{9}f)P_4$$
$$+\frac{1}{3}\omega^2r^2(1-P_2).$$

The equation to the surface will be of the form (8), and the transformations (12) hold good.

The conditions that the surface shall be level are, as before, that in V the coefficients of P_2 and P_4 shall vanish when r has the value (8).

These conditions are

$$\frac{2}{3}(1+\mu)a^2h(1-h)(1+\frac{20}{7}h)-\frac{2}{5}a^2h(1+\frac{2}{7}h)(1+\frac{11}{7}h)$$
$$-\frac{\omega^2a^2}{4\pi w}(1+\frac{2}{7}h)=0$$

$$8(1+\mu)a^2(f-\frac{1}{2}h^2)-\frac{72}{35}a^2h^2+\frac{8}{3}a^2(\frac{9}{2}h^2-f)+\frac{6\omega^2a^2}{\pi w}h=0\ ;$$

whence
$$h(1+\frac{11}{7}h)=\frac{15}{16}\frac{\omega^2}{\pi w}\cdot\frac{1}{1+\frac{5}{2}\mu}\quad\ldots\ldots\quad(43)$$

$$f(1+\frac{3}{2}\mu)=(\frac{6}{5}+\frac{3}{4}\mu)h^2-\frac{9\omega^2h}{8\pi w}.$$

To the first order of small quantities $\frac{\omega^2}{\pi w}=\frac{16}{15}(1+\frac{5}{2}\mu)h$, so that the second equation becomes

$$f=\frac{-\frac{9}{4}\mu h^2}{1+\frac{3}{2}\mu}\quad\ldots\ldots\ldots\quad(43)$$

If μ vanishes f also vanishes, and the surface is a true ellipsoid, as obviously should be the case.

Let us apply these formulæ (43) to the case of the Earth. It is known that $\omega^2 a^3/M$ is about $\frac{1}{288}$, and it may be denoted by m, although the meaning of that symbol is slightly changed from that which it bears elsewhere.

Then
$$m=\frac{\omega^2}{\frac{4}{3}\pi w(1+\mu)}, \text{ and}$$

$$h(1+\tfrac{11}{7}h)=\tfrac{5}{4}m\frac{1+\mu}{1+\frac{5}{2}\mu}$$

$$f=-(\tfrac{5}{4}m)^2\frac{\frac{9}{4}\mu(1+\mu)^2}{(1+\frac{3}{2}\mu)(1+\frac{5}{2}\mu)^2}.$$

The equation which determines the value of μ which makes f a maximum is

$$\frac{1}{\mu}-\frac{3}{2+\mu}+\frac{2}{1+\mu}-\frac{10}{2+5\mu}=0.$$

This reduces to the quadratic $\mu^2-\frac{1}{4}\mu-\frac{1}{2}=0$, of which the positive root is

$$\mu=\tfrac{1}{8}[1+\sqrt{33}]=\cdot 84307.$$

The departure from the true ellipsoidal figure is greatest when the nucleus forms $\frac{843}{1843}$ or $\cdot 457$ of the whole mass, and in this case

$$f=-\cdot 2946(\tfrac{5}{4}m)^2.$$

Taking $\frac{5}{4}m=\frac{1}{231}$,

$$f=-\cdot 0000055.$$

The Earth's equatorial radius is about 6,378,000 metres, and the depression of the surface below the true ellipsoid in latitude 45° is $\frac{1}{4}af$, which gives 8·8 metres for this ideal case.

It is clear that the depression in actuality must be considerably less than this, and we shall hereafter see reason to believe that it is about one-third of this maximum value.

§ 9. *Evaluation of the actual departure of the Earth's Figure from true Ellipticity.*

In order to determine the superficial value of f it is necessary to make some definite hypothesis as to the law of internal density.

The theory of the Earth's figure has been worked out according to several hypotheses as to the internal density. Two of these may be described as more prominent than others; they are the hypotheses of Laplace and of Roche. The results derived from both these theories are conformable to our knowledge, and as Roche's hypothesis seems more tractable than the other I shall adopt it.

Roche then supposes that the mean density w_0 of all the matter lying inside of equatorial radius a is expressed by a formula

$$w_0=\rho[1-\mathrm{k}(\frac{a}{\mathrm{a}})^2.]$$

The mean density of the whole Earth is clearly given by $\mathrm{w}_0=\rho(1-\mathrm{k})$.

Since $w=w_0-\frac{1}{3}a\frac{dw_0}{da}$, it follows that

$$w=\rho[1-\tfrac{5}{3}\mathrm{k}(\frac{a}{\mathrm{a}})^2] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

This is only true as a first approximation, but it suffices for the present. I now put

$$x=\mathrm{k}(\frac{a}{\mathrm{a}})^2$$

and change the independent variable from a to x in the differential equations for f and h, the latter only being taken to the first order of small quantities.

The equations (31) and (23) then become

$$\left.\begin{aligned}
&x(1-x)\frac{d^2h}{dx^2}+\tfrac{1}{2}(7-11x)\frac{dh}{dx}-h=0.\\
&x(1-x)\frac{d^2f}{dx^2}+\tfrac{7}{2}(1-x)(\frac{df}{dx}-\frac{f}{x})-2x(\frac{df}{dx}+\tfrac{1}{2}\frac{f}{x})+Q=0,\\
&\text{where}\\
&Q=2h^2+13h(x\frac{dh}{dx})+16(x\frac{dh}{dx})^2-\frac{1}{x}[7(x\frac{dh}{dx})+10(x\frac{dh}{dx})^2].
\end{aligned}\right\} \quad (45)$$

The first of these is Roche's equation, and I proceed to find the solution.*

If it be assumed that

$$h=E\sum_0^\infty H_n x^n,$$

where $H_0=1$, it is easy to prove that

$$H_{n+1}=\frac{n^2+\frac{9}{2}n+1}{n^2+\frac{9}{2}n+\frac{7}{2}}H_n.$$

Then if (n) denotes $\dfrac{n^2+\frac{9}{2}n+1}{n^2+\frac{9}{2}n+\frac{7}{2}}$

$$h=E[1+(0)x+(0)(1)x^2+(0)(1)(2)x^3+\ \ldots\ ].$$

* Tisserand, *Mécan. Cél.* vol. ii. A full account of the researches of Legendre, Laplace, Roche, Radau, Tisserand, Callandreau, and of others is given in this work.

Translating this into numbers I find

$$\frac{h}{E}=1+\frac{2}{7}x+\frac{13}{3^2.7}x^2+\frac{52}{3^3.11}x^3+\frac{47}{3^3.11}x^4+\frac{658}{3^4.5.11}x^5+\frac{31913}{3^5.5.11.17}x^6+\ .\qquad(46)$$

From this I make the following series of deductions :—

$$\frac{h^2}{E^2}=1+\frac{4}{7}x+\frac{218}{3^2.7^2}x^2+\frac{6812}{3^3.7^2.11}x^3+\frac{20045}{3^4.7^2.11}x^4+\frac{3896}{3^5.5.7}x^5+\frac{24210052}{3^6.5.7.11^2.17}x^6\ .\ .\qquad(47)$$

$$\frac{h}{E^2}\left(x\frac{dh}{dx}\right)=\frac{2}{7}x+\frac{218}{3^2.7^2}x^2+\frac{3406}{3^2.7^2.11}x^3+\frac{40090}{3^4.7^2.11}x^4+\frac{1948}{3^5.7}x^5+\frac{24210052}{3^5.5.7.11^2.17}x^6\ .\ .\qquad(48)$$

$$\frac{1}{E}\left(x\frac{dh}{dx}\right)=\frac{2}{7}x+\frac{26}{3^2.7}x^2+\frac{52}{3^2.11}x^3+\frac{188}{3^3.11}x^4+\frac{658}{3^4.11}x^5+\frac{63826}{3^4.5.11.17}x^6+\ .\ .\qquad(49)$$

$$\frac{1}{E^2}\left(x\frac{dh}{dx}\right)^2=\frac{4}{7^2}x^2+\frac{104}{3^2.7^2}x^3+\frac{20540}{3^4.7^2.11}x^4+\frac{4960}{3^4.7.11}x^5+\frac{251176}{3^5.7.11}x^6+\ .\qquad(50)$$

By means of these developments I find that the function Q in (45) is given by

$$\frac{Q}{E^2}=\frac{256}{3^2.7^2}x+\frac{7024}{3^2.7^4.11}x^2+\frac{13120}{3^2.7^2.11}x^3+\frac{578128}{3^5.7^2.11}x^4+\frac{116120320}{3^4.5.7.11^2.17}x^5$$

Then, assuming $f=E^2\sum_1^\infty K_n x^n$, and substituting in the second of (45), we get

$$\Sigma[n(n+\tfrac{9}{2})K_{n+1}-(n^2+\tfrac{9}{2}n-\tfrac{5}{2})K_n]x^n+Q=0,$$

or $(\frac{11}{2}K_2-3K_1)x+(13K_3-\frac{21}{2}K_2)x^2+(\frac{45}{2}K_4-20K_3)x^3$

$$+(34K_5-\tfrac{63}{2}K_4)x^4+(\tfrac{95}{2}K_6-45K_5)x^5+\ .\ .\ +Q=0$$

The coefficients of the several powers of x are to be equated to zero, and the successive equations solved. Carrying out this process I find

$$\left.\begin{aligned}
K_2&=\frac{6}{11}K_1-\frac{512}{3^2.7^2.11} &&=\cdot54545K_1-\cdot15545\\
K_3&=\frac{63}{11.13}K_1-\frac{12400}{3^2.7^2.11.13} &&=\cdot44056K_1-\cdot19663\\
K_4&=\frac{56}{11.13}K_1-\frac{167424}{3^4.7^2.11.13} &&=\cdot39161K_1-\cdot29499\\
K_5&=\frac{882}{11.13.17}K_1-\frac{11668616}{3^5.7^2.11.13.17} &&=\cdot36281K_1-\cdot40312\\
K_6&=\frac{15876}{11.13.17.19}K_1-\frac{15778709488}{3^5.5.7^2.11^2.13.17.19} &&=\cdot34372K_1-\cdot52164
\end{aligned}\right\}\qquad(51)$$

Extrapolated $K_7 \qquad = \cdot330K_1- \ \cdot635$

The coefficient K_1 remains indeterminate as yet, and I must now show how it is to be found.

The second of equations (20), (21), and (23) are as follows :—

$$f-\tfrac{3}{2}h^2+ah\frac{dh}{da}+\frac{3}{2w_0a^7}S_4-\frac{a^2}{3w_0}T_4=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

$$\frac{df}{da}-\frac{5f}{a}+\frac{27}{2}\frac{h^2}{a}-7h\frac{dh}{da}+a\left(\frac{dh}{da}\right)^2-\frac{27}{2w_0a^8}S_4=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

$$\frac{d^2f}{da^2}+6\frac{w}{w_0}\frac{df}{ada}-\left(20-6\frac{w}{w}\right)\frac{f}{a^2}+12\left(1-\frac{w}{w_0}\right)\frac{h^2}{a^2}+\left(4-18\frac{w}{w}\right)\frac{hdh}{ada}$$
$$-\left(1+9\frac{w}{w}\right)\left(\frac{dh}{da}\right)^2=0 \quad . \quad . \quad . \quad . \quad (c)$$

In obtaining (*b*) from (*a*) we multiplied (*a*) by w_0/a^2, differentiated, and divided by w_0/a^2. When x is independent variable we multiply by $(1-x)/x$, perform on the result the operation $x^4\frac{d}{dx}$, and divide by $(1-x)/x$.

Supposing all the functions to be expressed in series of powers of x, the equation (*a*) may be taken to be

$$P_1x+P_2x^2+\ .\ .\ .\ +P_nx^n+\ .\ .\ .\ =0 \quad . \quad . \quad . \quad . \quad (a')$$

It must be understood that the P's are numbers and not spherical harmonics. Then the equation (*b*) would be

$$(P_2-P_1)x^{\frac{1}{3}}+(2P_3-P_2-P_1)x^{\frac{4}{3}}+(3P_4-P_3-P_2-P_1)x^{\frac{7}{3}}$$
$$+(4P_5-P_4-P_3-P_2-P_1)x^{\frac{10}{3}}+\ .\ .\ .\ =0 \quad . \quad (b')$$

Again, (*c*) was derived from (*b*) by multiplication by w_0a^8, differentiation, and division by w_0a^8. When x is independent variable we multiply by $x^4(1-x)$, perform the operation $x^4\frac{d}{dx}$, and divide by $x^4(1-x)$. Hence (*c*) must be equivalent to

$$11(P_2-P_1)x+(2.13P_3-15P_2-11P_1)x^2+(3.15P_4-19P_3-15P_2$$
$$-11P_1)x^3+(4.17P_5-21P_4-19P_3-15P_2-11P_1)x^4+\ .\ .\ .=0 \quad (c')$$

Now the coefficients in f were evaluated by equating to zero the coefficients of the successive powers of x in (*c*) or (*c*′). Therefore

$$P_2-P_1=0,\ 2.13P_3-15P_2-11P_1=0,\ \text{and so forth.}$$

These equations are satisfied by

$$P_1=P_2=P_3=\ .\ .\ .\ =P_n\,;$$

but one of the coefficients, say P_1, remains indeterminate.

The equation (b') is satisfied by the same condition; but in order that (a') may be satisfied it is necessary not only that all the *P's* should be equal, but that they should also vanish.

Accordingly (a) affords us one more condition from which K_1 will be determinable.

When x is the independent variable, the equation (a) may be written

$$f-\tfrac{3}{2}h^2+2h\left(\frac{xdh}{dx}\right)+\tfrac{3}{2}\frac{1}{x^{\frac{7}{2}}(1-x)}\int_0^x\left(1-\tfrac{5}{3}x\right)d\left[x^{\frac{7}{2}}\left(h^2-\tfrac{2}{9}f\right)\right]$$
$$-\frac{x}{3(1-x)}\int_x^k\left(1-\tfrac{5}{3}x\right)d\left(\frac{f}{x}\right)=0.$$

Since f/E^2 is expressible by a series beginning with K_1x, we shall be able to find K_1 by developing this equation in a series, but only carrying the development out as far as the first term.

I drop the factor E^2 for the sake of brevity.

Then, $f=K_1x$; $h^2=1+\frac{4}{7}x$, from (47); $h^2-\frac{2}{9}f=1+\frac{4}{7}x-\frac{2}{9}K_1x$;

$$\frac{d}{dx}\left[x^{\frac{7}{2}}\left(h^2-\tfrac{2}{9}f\right)\right]=x^{\frac{5}{2}}\left(\tfrac{7}{2}+\tfrac{18}{7}x-K_1x\right),$$

$$\left(1-\tfrac{5}{3}x\right)\frac{d}{dx}\left[x^{\frac{7}{2}}\left(h^2-\tfrac{2}{9}f\right]=x^{\frac{5}{2}}\left(\tfrac{7}{2}-\tfrac{137}{42}x-K_1x\right);\right.$$

$$\int_0^x\left(1-\tfrac{5}{3}x\right)d\left[x^{\frac{7}{2}}\left(h^2-\tfrac{2}{9}f\right)\right]=x^{\frac{7}{2}}\left(1-\tfrac{137}{189}x-\tfrac{2}{9}K_1x\right);$$

whence

$$\frac{3}{2x^{\frac{7}{2}}(1-x)}\int_0^x\left(1-\tfrac{5}{3}x\right)d\left[x^{\frac{7}{2}}\left(h^2-\tfrac{2}{9}f\right)\right]=\tfrac{3}{2}+\tfrac{26}{63}x-\tfrac{1}{3}K_1x.$$

Also $$-\tfrac{3}{2}h^2+2h\left(\frac{xdh}{dx}\right)=-\tfrac{3}{2}-\tfrac{2}{7}x.$$

Therefore as far as the first power of x the equation is

$$K_1x+\tfrac{8}{63}x-\tfrac{1}{3}K_1x-\tfrac{1}{3}x\int_0^k\left(1-\tfrac{5}{3}x\right)d\left(\frac{f}{x}\right)=0.$$

Thus, reintroducing the factor E^2,

$$K_1=-\tfrac{4}{21}+\frac{1}{2E^2}\int_0^k\left(1-\tfrac{5}{3}x\right)d\left(\frac{f}{x}\right).$$

But $\dfrac{f}{E^2x}=K_1+K_2x+\ldots+K_nx^{n-1}+\ldots,$

Therefore

$$\left(1-\tfrac{5}{3}x\right)\frac{d}{dx}\left(\frac{f}{E^2x}\right)=K_2+\left(2K_3-\tfrac{5}{3}K_2\right)x+\ldots$$
$$+\left[(n+1)K_{n+2}-\tfrac{5}{3}nK_{n+1}\right]x^n+\ldots$$

and

$$\frac{1}{E^2}\int_0^{k}(1-\tfrac{5}{3}x)\,d\left(\frac{f}{x}\right)=K_2\mathrm{k}+(K_3-\tfrac{5}{6}K_2)\mathrm{k}^2+\ldots$$

$$+\left(K_{n+2}-\frac{5n}{3(n+1)}K_{n+1}\right)\mathrm{k}^{n+1}+\ldots$$

On substituting for the K's their values, I find

$$K_1+\tfrac{4}{21}=K_1(\cdot 27273\mathrm{k}-\cdot 00699\mathrm{k}^2-\cdot 04895\mathrm{k}^3-\cdot 06335\mathrm{k}^4-\cdot 07002\mathrm{k}^5-\cdot 0737\mathrm{k}^6\ldots)$$

$$-(\cdot 07773\mathrm{k}+\cdot 03355\mathrm{k}^2+\cdot 03826\mathrm{k}^3+\cdot 01719\mathrm{k}^4-\cdot 00793\mathrm{k}^5-\cdot 04475\mathrm{k}^6\ldots)$$

To find k we have the equations

$$2\frac{\Sigma nA_n\mathrm{k}^n}{\Sigma A_n\mathrm{k}^n}=2\frac{\mathrm{k}d\mathrm{h}}{\mathrm{h}d\mathrm{k}}=\frac{\mathrm{a}d\mathrm{h}}{\mathrm{h}d\mathrm{a}}$$

$$=\tfrac{5}{2}\frac{\mathrm{m}}{\mathrm{h}}-2+\tfrac{18}{7}\mathrm{h}-\tfrac{41}{7}\mathrm{m}-\tfrac{75}{14}\frac{\mathrm{m}^2}{\mathrm{h}}.$$

$$\mathrm{h}=\mathrm{e}-\tfrac{25}{14}\mathrm{e}^2-\tfrac{1}{7}\mathrm{f}.$$

The solution is virtually contained in the table of § 12 below.* From this it appears that when e is $\frac{1}{297}$, k is ·464.

Now with k=·464 I find

$$K_1(\cdot 11426)-\cdot 0464=K_1+\frac{4}{21};$$

whence on substitution in (51)

$$K_1=-\cdot 2674$$
$$K_2=-\cdot 3013$$
$$K_3=-\cdot 3144$$
$$K_4=-\cdot 3997$$
$$K_5=-\cdot 5002$$
$$K_6=-\cdot 6136$$

and $K_7=-\cdot 72$, by extrapolation.

With these values for the K's, and with k=·464,

$$\mathrm{f}=-\cdot 2632E^2.$$

But with k=·46, $\frac{\mathrm{h}}{E}=1\cdot 20465$, and with k=·47, $\frac{\mathrm{h}}{E}=1\cdot 21193$;

whence with k= $-$·464, $E=\frac{1}{358\cdot 5}$.

* In making the computations I treated f as zero.

Hence finally

$$\left.\begin{aligned} f &= -\cdot 00000205 \\ \tfrac{1}{4}af &= -3\cdot 26 \text{ metres} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (52)$$

This result shows that the Earth's surface is $3\frac{1}{4}$ metres below the ellipsoid in latitude 45°.

I have already used this value of f in the evaluation of gravity in equation (41) § 7.

M. Callandreau has not solved his differential equation which corresponds with mine, but he concludes that the depression in latitude 45° must be less than 5 metres.*

§ 10. *The departure from true Ellipticity according to Professor Wiechert's hypothesis.*

Professor Wiechert † has adduced forcible arguments in favour of the hypothesis that the Earth consists of an iron nucleus, of approximately uniform density, with a superposed layer of rock. He concludes that the nucleus must occupy about four-fifths of the radius. He considers the conditions that both nucleus and surface may be level, and gives valuable numerical tables.

The method of this paper permits us to give the conditions from which his tables were computed somewhat more succinctly than he does. I will therefore give my results in outline.

Let ρ', ρ be the densities of the nucleus and of the superficial layer; let a', e' or h', f' define the figure of the nucleus, and a, e or h, f that of the surface; also let ρ_0 be the mean density of the whole.

It is clear that

$$\left.\begin{aligned} \rho_0 &= \rho + (\rho' - \rho)\left(\frac{a'}{a}\right)^3 (1 + h - h'), \\ \text{whence } \frac{\rho'}{\rho_0} &= \frac{\rho}{\rho_0} - \left(1 - \frac{\rho}{\rho_0}\right)\left(\frac{a}{a'}\right)^3 (1 - h + h') \end{aligned}\right\} \quad . \quad . \quad . \quad (53)$$

The mean density ρ_0 may be taken as known, but if the values of ρ and of a'/a be assumed, the value of ρ' can only be rigorously found after the determination of h, h'. As a first approximation, very near the truth however, we may take $h = h'$, so that

$$\frac{\rho'}{\rho_0} = \frac{\rho}{\rho_0} - \left(1 - \frac{\rho}{\rho_0}\right)\left(\frac{a}{a'}\right)^3.$$

The integrals S_0, S_2, S_4, T_2, T_4, defined in (10) are only

* 'Ann. de l'Obs. de Paris,' *Mémoires*, t. xix. 1889, p. E. 51.

† 'Ueber die Massenvertheilung im Innern der Erde,' *Nachr. K. Gesell. zu Göttingen*, 1896–7, p. 221.

required when $a=a'$ at the boundary of the nucleus, and when $a=a$ at the surface.

When $a=a'$

$$S_0=\rho'a'^3(1-h')\ ;\ S_2=\rho'a'^5h'(1+\tfrac{2}{7}h');\ S_4=\rho'a'^7(h'^2-\tfrac{3}{35}f')\ ;$$

$$T_2=\rho(h-h')(1+\tfrac{17}{7}h+\tfrac{17}{7}h')\ ;\qquad T_4=\rho(\frac{f}{a^2}-\frac{f'}{a'^2}).$$

Similarly, the integrals corresponding to $a=a$ may be written down. If ρ' be then eliminated by means of (53), it will be found that they are

$$S_0=\rho_0a^3(1-h)$$

$$S_2=\rho_0a^3[(1-\frac{\rho}{\rho_0})h'(1-h+\tfrac{2}{7}h')a'^2+\frac{\rho}{\rho_0}h(1+\tfrac{2}{7}h)a^2]$$

$$S_4=\rho_0a^3[(1-\frac{\rho}{\rho_0})(h'^2-\tfrac{3}{35}f')a'^4+\frac{\rho}{\rho_0}(h^2-\tfrac{3}{35}f)a^4]$$

$$T_2=0,\qquad T_4=0.$$

The conditions that the surfaces a' and a may be level surfaces are given in (13) and (16), with the above values for the S and T integrals. I find that a considerable simplification in the expression results from considering $h(1+\tfrac{11}{7}h)$, $h'(1+\tfrac{11}{7}h')$ as the unknown quantities instead of simply h and h'. Accordingly I write

$$k=h(1+\tfrac{11}{7}h),\qquad k'=h'(1+\tfrac{11}{7}h').$$

It may be remarked in passing that $k=e-\tfrac{3}{14}e^2-\tfrac{1}{7}f$.

Without giving details I may state that the condition (13) leads to the two equations—

$$\left.\begin{aligned} k'(\frac{\rho'}{\rho_0}+\frac{3}{2}\frac{\rho}{\rho_0})-k(\frac{3}{2}\frac{\rho}{\rho_0})&=\frac{15}{16}\frac{\omega^2}{\pi\rho_0}+\frac{1}{7}\frac{\rho}{\rho_0}(k-k')(9k-5k')\\ -\frac{3}{2}k'(\frac{a'}{a})^2(1-\frac{\rho}{\rho_0})+k(\frac{5}{2}-\frac{3}{2}\frac{\rho}{\rho_0})&=\frac{15}{16}\frac{\omega^2}{\pi\rho_0}+\frac{3}{7}(1-\frac{\rho}{\rho_0})k'(k-k')(\frac{a'}{a})^2 \end{aligned}\right\}\quad(54)$$

We might first neglect the small terms on the right, and use the approximate value of ρ' on the left, solve the equations and then proceed to a second approximation. The approximate solution

$$\frac{k}{(2\rho'+3\rho)a^2+3(\rho_0-\rho)a'^2}=\frac{k'}{5\rho_0a^2}$$

$$=\frac{\dfrac{15\omega^2}{8\pi\rho_0}}{(5\rho_0-3\rho)(2\rho'+3\rho)a^2-9\rho(\rho_0-\rho)a'^2}$$

is, however, very near the truth, because the small terms on the

right not only depend on the squares of the ellipticity, but also involve $k-k'$, which is itself much smaller than either k or k'.

In these equations we have, of course, $\frac{15\omega^2}{8\pi\rho_0}=\frac{5}{2}m(1-\frac{3}{2}m)$.

Now turning to the condition (16), in which it is clearly permissible to write k, k', for h, h', I find

$$f\left(\frac{2\rho'}{\rho}+1\right)-f'\left(\frac{a'}{a}\right)^2=0,$$

$$-f\left(1-\tfrac{1}{3}\frac{\rho}{\rho_0}\right)+\tfrac{1}{3}f'\left(1-\frac{\rho}{\rho_0}\right)\left(\frac{a'}{a}\right)^4=\tfrac{3}{2}\left(1-\frac{\rho}{\rho_0}\right)\left\{k-k'\left(\frac{a'}{a}\right)^2.\right\}$$

From this

$$f=\frac{-\frac{9}{2}a^2(ka^2-k'a'^2)^2}{\left(3+2\frac{\rho}{\rho_0-\rho}\right)a^6-\frac{a'^6}{1+2\rho'/\rho}} \quad . \quad . \quad . \quad . \quad (55)$$

If ρ' were infinite and a' zero, but $\rho'a'^3=\mu\rho a^3(1-h)$, we ought to come back on the result for the nucleus of infinitely small dimensions in § 8; and this is so.

In one of the cases considered by Professor Wiechert he took $\rho=3{\cdot}2$, $\rho'=8{\cdot}206$, $a'/a={\cdot}78039$, and found the ellipticity of the surface to be $\frac{1}{297}$. The case corresponds closely with that of the Earth. He also computed a certain function from which my f might be derived. I find, however, by computation directly from (55), that $f=-{\cdot}00000175$, and $\frac{1}{4}af=-2{\cdot}79$ metres.

With Roche's hypothesis I found $f=-{\cdot}00000205$, and $\frac{1}{4}af=-3{\cdot}26$ metres. Thus the two hypotheses lead to nearly the same result.

§ 11. *Solution of the Differential Equation for h.*

I propose to solve the equation (31) with Roche's hypothesis, and thus to estimate the contribution of the terms of the second order to the value of h.

As in § 9, x is to be the independent variable.

The expression for w in (44) is no longer sufficient, but a term of the first order must be included in it.

It was proved in (32) that

$$w=w_0\left[1+\tfrac{1}{3}\left(1+\tfrac{1}{3}a\frac{dh}{da}\right)\frac{adw_0}{w_0da}\right].$$

Now $w_0=\rho(1-x)$ and $a\frac{d}{da}=2x\frac{d}{dx}$, so that

$$w=\rho\left[1-\tfrac{5}{3}x-\tfrac{4}{9}x\left(x\frac{dh}{dx}\right)\right],$$

and

$$w_0-w=\tfrac{2}{3}\rho x\left[1+\tfrac{2}{3}\left(x\frac{dh}{dx}\right)\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (55)$$

When x is introduced as independent variable in (31), and when the equation is divided by 4, the terms of the first order assume the form given in the first of (45). Then by aid of (55) the terms of the second order are easily determined, and the equation will be found to assume the following form :—

$$x(1-x)\frac{d^2h}{dx^2}+\tfrac{1}{2}(7-11x)\frac{dh}{dx}-h+P-R=0$$

where

$$P=\tfrac{7}{3}h^2+\tfrac{52}{21}\left[h\left(x\frac{dh}{dx}\right)+\left(x\frac{dh}{dx}\right)^2\right]$$

$$R=\tfrac{2}{3}m\left(h+2x\frac{dh}{dx}\right). \qquad \ldots \quad (56)$$

In the last of these m denotes $\frac{3\omega^2}{4\pi w_0}$; this is equal to $\frac{3\omega^2}{4\pi \mathrm{w}_0}\cdot\frac{\mathrm{w}_0}{w_0}$ or $\mathrm{m}\frac{1-\mathrm{k}}{1-x}$. Accordingly

$$R=\tfrac{2}{3}\mathrm{m}(1-\mathrm{k})\frac{h+2x\frac{dh}{dx}}{1-x} \qquad \ldots\ldots \quad (56)$$

By means of the series (47), (48), and (49) I find

$$P=E^2\Big\{\frac{7}{3}+\frac{100}{7^2}x+\frac{23890}{3^3.7^3}x^2+\frac{149084}{3^4.7^2.11}x^3+\frac{4134965}{3^5.7^3.11}x^4+\frac{115400024}{3^6.5.7^2.11}x^5$$
$$+\frac{1658730884}{3^7.7^2.11^2.17}x^6+\ldots\Big\}$$

or

$$P=\mathrm{E}^2\{\tfrac{7}{3}+2{\cdot}0408x+2{\cdot}5796x^2+3{\cdot}4149x^3+4{\cdot}5100x^4$$
$$+5{\cdot}8738x^5+7{\cdot}5248x^6+9{\cdot}45x^7+\ldots\}$$

the last term being extrapolated.

Now we saw in the last section that for the Earth the reciprocal of E was 358·5. As a fact I have here used the value 361·8, and it does not seem worth while to recompute on account of this small change in E.

Then

$$P=E\{{\cdot}006450+{\cdot}005641x+{\cdot}007131x^2+{\cdot}009440x^3$$
$$+{\cdot}012467x^4+{\cdot}016237x^5+{\cdot}020801x^6+{\cdot}0261x^7+\ldots\}$$

When the fractions in (46) and (49) are expressed in decimals, I find

$$h+2x\frac{dh}{dx}=E\{1+{\cdot}85714x+1{\cdot}03175x^2+1{\cdot}22559x^3$$
$$+1{\cdot}42424x^4+1{\cdot}62469x^5+1{\cdot}82597x^6+2{\cdot}028x^7+\ldots\}$$

And

$$\frac{h+2x\dfrac{dh}{dx}}{1-x}=E\{1+1{\cdot}85714x+2{\cdot}88889x^2+4{\cdot}11448x^3$$
$$+5{\cdot}53872x^4+7{\cdot}16341^5+8{\cdot}98938x^6+11{\cdot}016x^7\ \ldots\}$$

This last must be multiplied by $\frac{2}{3}$m(1−k) in order to find R. Now m=·00346, k=·464; so that the factor is ·001236. Then

$$R=E\{\cdot001236+\cdot002296x+\cdot003572x^2+\cdot005087x^3$$
$$+\cdot006848x^4+\cdot008857x^5+\cdot011114x^6+\cdot0136x^7+\ \ldots\}$$

Finally

$$\frac{P-R}{E}=\cdot005214+\cdot003345x+\cdot003559x^2+\cdot004353x^3$$
$$+\cdot005619x^4+\cdot007380x^5+\cdot009687x^6+\cdot0125x^7+\ \ldots$$

I now assume as before,

$$h=E\sum_0^\infty H_n x^n,$$

so that the differential equation (56) gives

$$\Sigma[(n^2+\tfrac{9}{2}n+\tfrac{7}{2})H_{n+1}-(n^2+\tfrac{9}{2}n+1)H_n]x^n+\frac{P-R}{E}=0.$$

When the coefficients of the successive powers of x are equated to zero the first equation is

$$\tfrac{7}{2}H_1-H_0=-\cdot005214.$$

If we assume $H_0=1$, which is clearly permissible,

$$H_1=\tfrac{2}{7}-\cdot001490.$$

Then from the successive equations I find

$$H_2=\frac{13}{3^2.7}-\cdot001448$$

$$H_3=\frac{52}{3^3.11}-\cdot001444$$

$$H_4=\frac{47}{3^3.11}-\cdot001473$$

$$H_5=\frac{658}{3^4.5.11}-\cdot001524$$

$$H_6=\frac{31913}{3^5.5.11.17}-\cdot001594.$$

$$H_7=\frac{583552}{3^8.5.11.17.19}-\cdot001698.$$

The first part of each of these coefficients is the corresponding coefficient in the first approximation, given in (46). If, therefore, we denote by δh the correction to be applied to the first approximation as arising from the terms of the second order, we have

$$\delta h = -E\{\cdot 00149x + \cdot 00145x^2 + \cdot 00144x^3 + \cdot 00147x^4 + \cdot 00152x^5 + \cdot 00159x^6 + \cdot 00170x^7 + \ldots\}$$

By an empirical summation of this series, we may assert that a fair approximation to the result is given by

$$\delta h = -\cdot 0015\frac{Ex}{1-x}.$$

But $\frac{2}{3}\frac{x}{1-x} = 1 - \frac{w}{w_0}$, so that the correction becomes

$$\delta h = -\cdot 00225E\left(1-\frac{w}{w_0}\right).$$

or since E is about $\frac{1}{380}$,

$$\delta h = -\cdot 0000062\left(1-\frac{w}{w_0}\right).$$

The superficial value of h corresponding to $e = \frac{1}{297}$ is $\cdot 003349$, and

$$\frac{\delta h}{h} = -\cdot 0019\left(1-\frac{w}{w_0}\right).$$

It is, however, better to look at this correction from another point of view. If h_0 denotes h as derived from the first approximation, we have, by means of the empirical solution,

$$h = h_0 - \cdot 0015\frac{Ex}{1-x};$$

so that

$$x\frac{dh}{dx} = x\frac{dh_0}{dx} - \cdot 0015\frac{Ex}{(1-x)^2}.$$

We have seen in § 9 that k in Roche's hypothesis is derived from the equation

$$\frac{2\Sigma nA_n\mathrm{k}^n}{\Sigma A_n\mathrm{k}^n} = \frac{5}{2}\frac{\mathrm{m}}{\mathrm{h}} - 2 + \frac{18}{7}\mathrm{h} - \frac{41}{7}\mathrm{m} - \frac{75}{14}\frac{\mathrm{m}^2}{\mathrm{h}}.$$

It now appears that, when terms of the second order are included in the differential equation for h, the left-hand side of this equation becomes

$$\frac{2\left(\Sigma nA_n\mathrm{k}^n - \cdot 0015\frac{\mathrm{k}}{(1-\mathrm{k})^2}\right)}{\Sigma A_n\mathrm{k}^n - \cdot 0015\frac{\mathrm{k}}{1-\mathrm{k}}}$$

Now I found that when $k = \cdot 464$, $\Sigma A_n k^n = 1 \cdot 20756$, $\Sigma n A_n k^n = \cdot 33666$.

Therefore

$$\Sigma n A_n k^n - \cdot 0015 \frac{k}{(1-k)^2} = \Sigma n A_n k^n \left(1 - \frac{150}{33666} \cdot \frac{\cdot 464}{(\cdot 536)^2}\right)$$

$$= \Sigma n A_n k^n (1 - \cdot 00720).$$

$$\Sigma A_n k^n - \cdot 0015 \frac{k}{1-k} = \Sigma A_n k_n \left(1 - \frac{150}{120756} \cdot \frac{464}{536}\right)$$

$$= \Sigma A_n k^n (1 - \cdot 00108).$$

Since $\frac{1 - \cdot 00720}{1 - \cdot 00108} = 1 - \cdot 00612 = \cdot 99388$, it follows that the left-hand side of the equation for k is

$$\cdot 994 \left(\frac{2 \Sigma n A_n k^n}{\Sigma A_n k^n}\right).$$

The principal effect of the terms of the second order will therefore be slightly to alter the value of k which satisfies the observed conditions. In every hypothesis as to the internal density there is some parameter derivable from observation, and a similar investigation would show that its value is but slightly affected by the terms of the second order. It is clear, then, that there is not much to be gained by pursuing this investigation further.

§ 12. *The Moments of Inertia, the Precessional Constant, and the Ellipticity of the Earth.*

It was shown in (6) of § 1 that

$$C = \tfrac{8}{15}\pi \int_0^a w d[a^5(1 - e + \tfrac{4}{7}f)].$$

If the terms of the second order be omitted we may drop f and replace e by h. Also to the first order $S_2 = \int_0^a w d(a^5 h)$; and by (35)

$$S_2 = \frac{5M}{4\pi} a^2 [h - \tfrac{1}{2}m].$$

Hence $$C = \tfrac{8}{3}\pi \int_0^a w a^4 da - \tfrac{2}{3} M a^2 (h - \tfrac{1}{2}m).$$

It was shown in (32) that

$$w = w_0 + \tfrac{1}{3} a \frac{dw_0}{da} + \tfrac{1}{9} a^2 \frac{dh}{da} \frac{dw_0}{da},$$

so that

$$\int_0^a wa^4da=\int_0^a w_0a^4da+\tfrac{1}{3}\int_0^a a^5dw_0+\tfrac{1}{9}\int_0^a a^6\frac{dh}{da}dw_0.$$

If the middle term in this expression be integrated by parts we have a term $-\frac{5}{3}\int_0^a w_0a^4da$, which will fuse with the first term. Therefore

$$\int_0^a wa^4da=\tfrac{1}{3}\mathrm{w}_0\mathrm{a}^5-\tfrac{2}{3}\int_0^a w_0a^4da+\tfrac{1}{9}\int_0^a a^6\frac{dh}{da}dw_0,$$

and

$$C=\tfrac{8}{9}\pi\mathrm{w}_0\mathrm{a}^5\left[1-\frac{2}{\mathrm{w}_0\mathrm{a}^5}\int_0^a w_0a^4da+\frac{1}{3\mathrm{w}_0\mathrm{a}^5}\int_0^a a^6\frac{dh}{da}dw_0\right]-\tfrac{2}{3}\mathrm{Ma}^2(\mathrm{h}-\tfrac{1}{2}\mathrm{m})$$

But to the order of approximation here adopted

$$\tfrac{8}{9}\pi\mathrm{w}_0\mathrm{a}^5=\tfrac{2}{3}\mathrm{Ma}^2(1+\mathrm{h}).$$

Therefore

$$C=\tfrac{2}{3}\mathrm{Ma}^2\left[1-\frac{2(1+\mathrm{h})}{\mathrm{w}_0\mathrm{a}^5}\int_0^a w_0a^4da+\frac{1}{3\mathrm{w}_0\mathrm{a}^5}\int_0^a a^6\frac{dh}{da}dw_0+\tfrac{1}{2}\mathrm{m}\right].$$

We now make use of M. Radau's transformation. It was proved in (34), § 5, that

$$\mathrm{w}_0\mathrm{a}^5\surd(1+\eta_1)=5(1+\lambda)\int_0^a w_0a^4da,$$

where $1+\lambda$ is a mean value of a certain function.

Therefore

$$-\frac{2(1+\mathrm{h})}{\mathrm{w}_0\mathrm{a}^5}\int_0^a w_0a^4da=-\tfrac{2}{5}\frac{(1+\mathrm{h})\surd(1+\eta_1)}{1+\lambda}.$$

Now

$$\int_0^a a^6\frac{dh}{da}dw_0=\mathrm{w}_0\mathrm{a}^6\frac{\mathrm{dh}}{\mathrm{da}}-\int_0^a w_0\left(6a^5\frac{dh}{da}+a^6\frac{d^2h}{da^2}\right)da.$$

But h satisfies the differential equation

$$\frac{d^2h}{da^2}+6\frac{w}{w_0}\frac{dh}{ada}-6\left(1-\frac{w}{w_0}\right)\frac{h}{a^2}=0,$$

and

$$\frac{dw_0}{da}=-\frac{3}{a}(w_0-w).$$

Therefore

$$\int_0^a w_0\left(6a^5\frac{dh}{da}+a^6\frac{d^2h}{da^2}\right)da=6\int_0^a(w_0-w)\left(ha^4+a^5\frac{dh}{da}\right)da$$

$$=6\int_0^a(w_0-w)ha^4da-2\int_0^a a^6\frac{dh}{da}dw_0.$$

Therefore

$$\int_0^a a^6 \frac{dh}{da} dw_0 = -w_0 a^5 h \eta_1 + 6 \int_0^a (w_0 - w) h a^4 da.$$

Now let

$$\left.\begin{aligned} \Delta_1 &= \tfrac{2}{5}(1+h)\sqrt{(1+\eta_1)}\frac{\lambda}{1+\lambda} \\ \Delta_2 &= -\tfrac{1}{3} h \eta_1 + \frac{2}{w_0 a^5}\int_0^a (w_0 - w) h a^4 da \\ \Delta &= \Delta_1 + \Delta_2 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (57)$$

and we have

$$C = \tfrac{2}{3} M a^2 [1 - \tfrac{2}{5}(1+h)\sqrt{(1+\eta_1)} + \tfrac{1}{2} m + \Delta] \quad . \quad . \quad (57)$$

The only part of the expression for C which involves the law of internal density is Δ, and we shall see that Δ is very small compared with unity.

M. Callandreau has established a formula for C with which, as far as I can make out, mine agrees.*

It is clear that the two parts of Δ originate in quite different ways, Δ_1 depending on the equation for the internal ellipticity, and Δ_2 depending on the terms of the second order.

It is first necessary to evaluate λ from the equation

$$1 + \lambda = \frac{\tfrac{1}{5} w_0 a^5 \sqrt{(1+\eta_1)}}{\int_0^a w_0 a^4 da} \quad . \quad . \quad . \quad . \quad . \quad . \quad (58)$$

where $$1 + \eta_1 = \tfrac{5}{2}\frac{m}{h} - 1 + \tfrac{18}{7} h - \tfrac{41}{7} m - \tfrac{75}{14}\frac{m^2}{h}.$$

It is not hard to obtain a close approximation to λ when Laplace's hypothesis as to the density is adopted, but that hypothesis is not so tractable as Roche's, and I therefore adopt the latter.

According to Roche

$$w_0 = \rho(1 - x), \text{ where } x = k\left(\frac{a}{a}\right)^2.$$

Therefore

$$\int_0^a w_0 a^4 da = \tfrac{1}{2}\frac{\rho a^5}{k^{\frac{5}{2}}}\int_0^k (1 - x) x^{\frac{3}{2}} dx$$

$$= \tfrac{1}{5}\rho a^5 (1 - \tfrac{5}{7} k).$$

Accordingly $$1 + \lambda = \frac{1 - k}{1 - \tfrac{5}{7} k}\sqrt{(1+\eta_1)}.$$

Since $w_0 = \rho\,(1 - k)$, and with close approximation,

* *Bulletin Astronomique*, vol. xiv. 1897, p. 217.

$w = \rho(1-\frac{5}{3}k)$, we have $\rho = (\frac{5}{2}w_0 - \frac{3}{2}w)$, $k = \frac{3(w_0 - w)}{5w_0 - 3w}$ very nearly.
Hence we may also write

$$1+\lambda = \frac{\sqrt{(1+\eta_1)}}{1+\frac{3}{7}(1-w/w_0)}\text{*} \quad . \quad . \quad . \quad . \quad . \quad . \quad (59)$$

Therefore

$$\Delta_1 = \tfrac{2}{5}(1+h)[\sqrt{(1+\eta_1)} - 1 - \tfrac{3}{7}(1-w/w_0)] \quad . \quad . \quad (60)$$

It is now required to evaluate Δ_2.
With Roche's hypothesis

$$\frac{2}{w_0 a^5}\int_0^a (w_0 - w) h a^4 da = \tfrac{2}{3}\frac{\rho}{w_0} \cdot \frac{1}{k^{\frac{5}{2}}}\int_0^k h x^{\frac{5}{2}} dx.$$

I write the series (46) $h = E\sum_0^\infty A_n x^n$, and then

$$\frac{2}{w_0 a^5}\int_0^a (w_0 - w) h a^4 da = \tfrac{2}{3}\frac{E\rho}{w_0 k^{\frac{5}{2}}}\sum\int_0^k A_n x^{n+\frac{5}{2}} dx,$$

$$= \tfrac{4}{3}\frac{Ek}{1-k}\sum\frac{1}{2n+7}A_n k^n.$$

But $h = E\sum A_n k^n$, and therefore

$$\Delta_2 = \tfrac{1}{3}h\left[-\eta_1 + \frac{4k\sum\frac{1}{2n+7}A_n k^n}{(1-k)\sum A_n k^n}\right]$$

or

$$\Delta_2 = \tfrac{1}{3}h\left[-\eta_1 + 6\left(1-\frac{w}{w_0}\right)\frac{\sum\frac{1}{2n+7}A_n k^n}{\sum A_n k^n}\right] \quad . \quad . \quad . \quad (61)$$

In order to estimate the magnitude of the correction Δ I have computed it, and its two constituents, in the following table :—

* The approximation here consists in neglecting the variation of ellipticity in evaluating the density w from the mean density w_0. In Laplace's hypothesis $w = \rho\frac{\kappa}{a}\sin\frac{a}{\kappa}$. If we neglect the variation of ellipticity in determining the mean density w_0 from the density w, it will be found that

$$1+\lambda = \frac{1}{15}\frac{a^2}{\kappa^2}\frac{\sqrt{(1+\eta_1)}}{1-w/w_0}.$$

Since $\frac{w_0}{w} = \frac{\kappa^2}{a^2}\left(1-\frac{a}{\kappa}\cot\frac{a}{\kappa}\right)$, κ may be regarded as a function of w_0/w, and λ is seen to be a function of w_0/w and of η_1, as in the text.

Table of Results according to Roche's Hypothesis.

$$\left(m = \frac{1}{288 \cdot 41}\right).$$

	k	·1	·2	·3	·4	·46	·47	·5	·55
Ratio of mean to surface density	w_0/w =	1·08	1·2	1·4	1·8	2·314	2·446	3·0	5·4
Reciprocal of ellipticity	$\frac{1}{e}$ =	239·3	248·2	262·2	280·7	295·7	298·6	308·2	327·5
	$h \times 10^6$ =	4148	4001	3788	3541	3362	3329	3227	3037
Moment of inertia, uncorrected	$C \div \frac{2}{3} Ma^2$ =	·58728	·57137	·55088	·52360	·50245	·49847	·48557	·46036
	$\lambda \times 10^6$ =	47	184	387	548	516	493	422	99
First correction	$\Delta_1 \times 10^6$ =	19	79	174	262	258	248	218	54
Second correction ...	$\Delta_2 \times 10^6$ =	− 2	− 10	− 28	− 63	− 95	−102	−125	−173
Ratio of total correction to moment of inertia...	$\frac{2}{3}\frac{Ma^2\Delta}{C} \times 10^6$ =	29	120	265	380	322	293	192	−258

It will be observed that λ and Δ_1 reach maxima when k is ·4, whereas $-\Delta_2$ increases throughout as k increases. The last line gives the factor of augmentation of the uncorrected value of C. The columns k=·46 and ·47 are those which correspond to the case of the Earth most closely, and they show that C must be augmented by a factor 1·0003 when Δ is taken into account.

We are now in a position to give the formula for the Precessional Constant $\frac{C-A}{C}$.

It appears from (9), (10), (35), and (36) that

$$C-A=\tfrac{2}{3}\mathrm{Ma}^2[\mathrm{h}-\tfrac{1}{2}\mathrm{m}+\tfrac{9}{7}\mathrm{h}^2+\tfrac{1}{7}\mathrm{mh}+\tfrac{3}{4}\mathrm{m}^2] \quad . \quad . \quad (61)$$

So that, dividing (61) by (57),

$$\left.\begin{aligned} \frac{C-A}{C}&=\frac{\mathrm{h}-\frac{1}{2}\mathrm{m}+\frac{9}{7}\mathrm{h}^2+\frac{1}{7}\mathrm{mh}+\frac{3}{4}\mathrm{m}^2}{1-\frac{2}{3}(1+\mathrm{h})\sqrt{(1+\eta_1)}+\frac{1}{2}\mathrm{m}+\Delta}, \\ \text{where}\quad 1+\eta_1&=\tfrac{5}{2}\frac{\mathrm{m}}{\mathrm{h}}-1+\tfrac{18}{7}\mathrm{h}-\tfrac{41}{7}\mathrm{m}-\tfrac{75}{14}\frac{\mathrm{m}^2}{\mathrm{h}} \end{aligned}\right\} \quad . \quad (62)$$

We have reason to believe that the term Δ may be allowed for by first treating it as zero, and afterwards multiplying the result by ·9997.

The Precessional Constant is known with a high degree of accuracy, and I cannot but think that this investigation shows that it may be used for determining the actual ellipticity of the Earth's surface with perhaps as little error as by any other method. The uncertainty is, indeed, of a different kind, being dependent on our ignorance of the interior of the Earth. I reduce the formula (62) to numbers in the following manner. I assume a definite value for the ellipticity, namely $\mathrm{e}_0=\frac{1}{299}$ $=·00334448$. Then, with $\mathrm{f}=-·00000205$, h_0 is computed and found to be ·00332480. I take also $\mathrm{m}=·0034672$.

Now let N_0, D_0 be the numerator and denominator of (62), with these values of h, m, and with Δ put equal to zero. Then, if $N=N_0+\delta N$, $D=D_0+\delta D$, $\mathrm{h}=\mathrm{h}_0+\delta\mathrm{h}$ be the true values of those quantities, it is clear that

$$N=N_0+(1+\tfrac{18}{7}\mathrm{h}+\tfrac{1}{7}\mathrm{m})\delta\mathrm{h},$$

$$D=D_0-\tfrac{2}{3}\sqrt{(1+\eta_1)}\delta\mathrm{h}+\tfrac{1}{3}\frac{(1+\mathrm{h})}{\sqrt{(1-\eta_1)}}(\tfrac{5}{2}\frac{\mathrm{m}}{\mathrm{h}^2}-\tfrac{18}{7}-\tfrac{75}{14}\frac{\mathrm{m}^2}{\mathrm{h}^2})\delta\mathrm{h}.$$

From these we may compute δN and δD.

I find then,

$$N_0=·00161608, \qquad N=N_0(1+624·4\delta h),$$

$$D_0=·4991436, \qquad D=D_0(1+248·0\delta h).$$

Then $\frac{N_0}{D_0}=·00323771$, and since the denominator should be augmented by 1·0003, it follows that the corrected value of $\frac{N_0}{D_0}=·00323674$, and

$$\frac{C-A}{C}=\frac{N}{D}=·00323674(1+376·4\delta h).$$

The most generally accepted value of the precessional constant is ·003272, and this exceeds our corrected N_0/D_0 by ·00003526. Therefore

$$\delta h = \frac{\cdot 00003526}{376\cdot 4 \times \cdot 0032366} = \cdot 00002895.$$

But h_0 was ·00332480, so that h = ·0033537. If $\frac{25}{14}h^2 + \frac{1}{7}f$ be added to h, we obtain e; the result is

$$e = \cdot 0033734 = \frac{1}{296\cdot 4}.^*$$

I have, in fact, repeated the computation with this value of e, and find $\frac{N_0}{D_0} = \cdot 003273$, which only differs from the Precessional Constant by unity in the sixth place of decimals. Oppolzer † adopts the value ·003261 for the Precessional Constant, and this leads to $\frac{1}{297\cdot 5}$ as the value of the ellipticity.

Dr. Wiechert has considered the hypothesis that the Earth consists of an iron nucleus with a superstratum of rock. With the Precessional Constant at ·003272 it may be concluded from his table that the ellipticity is $\frac{1}{297\cdot 3}$.

These results, then, point to an ellipticity between $\frac{1}{296}$ and $\frac{1}{298}$, and they agree well with the results of all the methods of determining the ellipticity except that of the pendulum. Dr.

* As it is desirable that the ellipticity of the earth should be evaluated with all the accuracy possible, it may be well to advert to the augmentation of ellipticity which is due to the direct actions of the Moon and Sun.

The tide-generating potential of each of these bodies contains a term which is independent of the time, and to which there must correspond a permanent tide.

If i be the obliquity of the ecliptic; and m, c, e_0 the mass, mean distance and eccentricity of orbit for the Moon; while m', c', e'_0 represent the same for the Sun; the tide-generating potential contains the term,

$$\left[\frac{m}{c^3}\left(1 + \tfrac{3}{2}e_0^2\right) + \frac{m'}{c'^3}\left(1 + \tfrac{3}{2}e_0'^2\right)\right]\tfrac{3}{4}\left(1 - \tfrac{3}{2}\sin^2 i\right)r^2\left(\tfrac{1}{3} - \cos^2\theta\right).$$

This is equal to

$$(1\cdot 46035)\,\tfrac{3}{4}\frac{m}{c^3}\left(1 - \tfrac{3}{2}\sin^2 i + \tfrac{3}{2}e_0^2\right)r^2\left(\tfrac{1}{3} - \cos^2\theta\right).$$

The ellipticity of the Earth which corresponds with this term is

$$(1\cdot 46035)\,\frac{\frac{3m}{4M}\left(\frac{a}{c}\right)^3\left(1 - \tfrac{3}{2}\sin^2 i + \tfrac{3}{2}e_0^2\right)}{1 - \tfrac{3}{5}w/w_0} = \frac{\cdot 00000004708}{1 - \tfrac{3}{5}w/w_0}.$$

If we take $w_0/w = 2\cdot 1$, the ellipticity is ·0000006538. The meaning of this is that the Earth's surface is 28 cm. lower at the poles, and 14 cm. higher at the equator, than would be the case if the Sun and Moon were obliterated. This term may therefore be safely omitted.

† Helmert, *Höhere Geodäsie*, vol. ii. p. 437.

Helmert's * result from the pendulum is $\frac{1}{299\cdot26 \pm 1\cdot26}$, and is certainly slightly smaller than the value found here.

In the paper above referred to M. Callandreau has used the Precessional Constant for evaluating the ellipticity of the Earth, which he finds to be $\frac{1}{297\cdot4}$. The agreement of my work with his is thus very satisfactory.

Summary and Discussion.

The space in the neighbourhood of an oblate ellipsoid of revolution may be divided into three regions by two spheres touching it internally and externally. It is clearly possible to express the potential of such a solid homogeneous ellipsoid by series of spherical harmonics which are convergent both inside the smaller sphere and outside the larger one, but for the space between them the convergency is uncertain. In the treatment of the attractions of spheroids by means of spherical harmonics, it is usual to assume the ellipticity to be small, so that the region of possible divergency becomes negligible.

But this method is no longer certainly justifiable when we seek to carry the development as far as the squares of small quantities, and proof is needed of the applicability of the series within the middle region of space. If, having found our two series expressive of the potential for internal and for external space respectively, we determine the form of the surface inside the middle region at which these two potentials are continuous as far as the second order of small quantities, we find that the surface in question is that of the ellipsoid itself. The two series then form a continuous function at the surface of the ellipsoid, and they obviously satisfy the differential equation of the potential both inside and outside the ellipsoid. It follows that although the series were determined by a process which is open to doubt as respects the middle region, they lead to results which are trustworthy as far as the second order of small quantities.

There is, however, another method of finding the potential of the ellipsoid, by which the difficulty as to convergency is avoided. It is well known that the potential of a solid ellipsoid is expressible in a series of spherical harmonics, and that the series is convergent up to the surface, at least for all ellipsoids with eccentricity less than $\frac{1}{2}$. Also there is a rigorous expression in finite terms for the internal potential, involving only the second harmonic. If only the second power of the ellipticity be retained, these two expressions are found to be identical with those derived from integration, and the question of convergency is settled.

If an oblate ellipsoid of revolution be slightly distorted in any

* Vol. ii. p. 241.

way, the deformation being of the order of the square of the ellipticity, the additional terms in the potential may obviously be expressed by the ordinary formulæ of spherical harmonic analysis.

In the theory of the Earth's figure it is unnecessary to contemplate the existence of any other departure from true ellipticity than one expressible by a zonal harmonic of the fourth order. Three parameters are needed to express the surface of such a spheroid. If a and b denote the equatorial and polar radii, the first parameter is a the equatorial radius; the second is the ellipticity e defined as being equal to $\frac{a-b}{a}$; and it seems convenient to take as the third a quantity proportional to the elevation of the surface of the spheroid above that of the true ellipsoid in latitude 45°. If the third parameter be denoted by f, the elevation in question is $\frac{1}{4}af$.

I have found, however, that there is a gain in simplicity by displacing the ellipticity e from its position as the second parameter, and by substituting for it a parameter h, which is defined by

$$h = e - \tfrac{25}{14}e^2 - \tfrac{1}{7}f.$$

To the first order of small quantities it is clearly immaterial whether h or e be used, but the advantage of the change is found to arise when quantities of the second order are retained in the developments.

When the external and internal potentials of a homogeneous spheroid defined by a, h, f are known, it is easy to express by means of integrals the potential of a heterogeneous body built up by a succession of layers, each of which has its external and internal surfaces defined as a spheroid of the kind under consideration. When the object in view is the study of the figure of a planet, the potential corresponding to a uniform angular velocity must of course be added. The processes explained here are carried out in §§ 1 and 2.

It is generally assumed that the matter of which the Earth is formed is sufficiently plastic to permit the condition of hydrostatic equilibrium to be satisfied throughout the mass. Even if this condition is not rigorously correct, it must be nearly so.

In § 2 the condition of hydrostatic equilibrium is determined. It is expressed by two equations, of which the first corresponds to that ordinarily given for the ellipticity of internal strata, but it contains also terms of the second order. The second equation consists entirely of terms of the second order, and involves the parameter f. The advantage due to the substitution of h for e is now apparent, for the first equation is entirely independent of f. These two equations involve integrals which are eliminated by integration, and we obtain two differential equations of the second order for h and for f; the equation for h does not involve f (§§ 3, 4).

M. Radau has shown that it is possible to reduce the differential equation for the ellipticity to one of the first order, at least to a close degree of approximation. In § 5 his process is carried out with the retention of quantities of the second order. It appears that the approximation is even better than when only the terms of the first order are retained.

The formula for gravity is obtained in § 6. It was given for the first time by Airy, as already remarked in the Introduction. The results of pendulum experiments do not appear as yet to be sufficiently numerous or consistent, *inter se*, to render a revision of the value of the ellipticity of the Earth's surface practicable by aid of this more accurate formula for gravity.

The rates of change of h and of f at the earth's surface are determined in § 7. As a preliminary to the evaluation of the departure of the Earth's figure from true ellipticity, I then consider the figure of a homogeneous mass of fluid with a small heavy nucleus at its centre (§ 8). The departure is found to be greatest when the nucleus contributes ·457, and the fluid ·543 of the whole mass. For such a planet, with the same mean density, size, and length of day as the Earth, it is found that the surface is 8·8 metres below the true ellipsoid in latitude 45°. In the actual Earth the departure will certainly be less than this maximum.

The evaluation of f for a heterogeneous planet is only possible when the law of internal density is known. I have, then, adopted Roche's hypothesis, according to which the mean density of all the matter lying inside any surface of equal density is less than the central density by an amount which varies as the square of the equatorial radius of that surface. In the notation of the paper the law is expressed by $w_0=\rho[1-k(\frac{a}{\mathrm{a}})^2]$. It is found in § 9, by some rather tedious analysis and computation, that the surface is depressed in latitude 45° by $3\frac{1}{4}$ metres.

Dr. Wiechert has maintained that the Earth probably consists of an iron nucleus with a rocky superstratum. His theory leads to the conclusion that the depression in latitude 45° amounts to 2·75 metres (§ 10). The close agreement between the results of such diverse hypotheses as those of Roche and of Wiechert appears to justify us in maintaining with confidence that the level surface is depressed below the true ellipsoid by 3 metres in latitude 45°.

A solution of the differential equation for h in § 11 does not lead to results of much general interest, and I refer the reader to that section for details.

It has been stated in the introduction that M. Callandreau has treated these problems by methods which differ somewhat from mine. He has concluded, but without definitely solving the differential equation, that the depression in latitude 45° must be less than 5 metres.

In § 12 formulæ are found for the moment of inertia of the

Earth about its axis of rotation, and thence for the Precessional Constant. Similar formulæ have been found by M. Callandreau in the papers referred to above, but I think that my formulæ are somewhat more succinct and tractable than his.

In the various theories of the figure of the Earth which have been propounded up to recent times, the value of the Precessional Constant has always been appealed to as the test whereby the correctness of the hypothesis as to internal density may be tried. But it appears from M. Radau's remarkable investigation that the Earth's moment of inertia about the axis of rotation is in reality nearly independent of the law of internal density; and the difference between the greatest and least moments of inertia depends rigorously on superficial data. Accordingly, the value of the Precessional Constant may be inferred with a considerable degree of accuracy from the form of the surface, and it affords evidence of little weight as to the law of internal density. But although from this point of view the comparison of this constant with theory becomes almost nugatory, yet the very result which shows its uselessness in one respect points out its utility in another, for we may now appeal to it as affording the means for an independent evaluation of the ellipticity of the Earth's surface.

In § 12 an estimate is made of the amount by which the moment of inertia of the earth is affected by the law of internal density. A formula is found for the moment of inertia, which consists of the sum of two parts, the first being dependent only on superficial data, and the second on the law of internal density. From the numerical table of results given in that section it appears that if the moment of inertia C be computed as though the second part were non-existent, it must be multiplied by the factor 1·0003 in order to take into account the neglected portion. Since the moment of inertia C occurs in the denominator of the Precessional Constant, it is obvious that the uncorrected value should be multiplied by ·9997. Proceeding from these results and from the value of the constant, it appears that the ellipticity of the Earth's surface must be about $\frac{1}{297}$. M. Callandreau has arrived also at the same conclusion, and it is confirmed by Dr. Wiechert, although his suggested law of internal density differs very widely from that adopted by other investigators. This estimate of the ellipticity agrees well with that derived from all the other methods, except that of the pendulum, from which it is concluded that the ellipticity is about $\frac{1}{293}$. It may be hoped that the various results may be brought into closer agreement with one another when the great mass of pendulum results now accumulated has been reduced.

It has been contended by Tisserand that the ellipticity of the Earth's surface is greater than any value which it is possible to reconcile with the existence of internal hydrostatic equilibrium; and with the values of the constants used by him, this is certainly so. But it seems to me that when the terms of the second order are included, and when more recent data are employed, there is

but little evidence in favour of this conclusion. If Tisserand were correct, it would indicate that the internal layers of the earth are more elliptic than is consistent with the present angular velocity of rotation. On the other hand, Dr. Wiechert seeks to show that his iron nucleus is deficient in ellipticity. His argument does not, however, carry conviction to my mind, as the data seem to be too uncertain for any such conclusion. It is, I think, preferable to maintain that nothing can, as yet, be decided on this point.

Note on the Values of the Coefficients of the terms of the Third Order in the new Lunar Theory. By Ernest W. Brown, M.A.

In the Memoirs of the Society, vol. liii. pp. 163–202, I have given the values of the coefficients of all terms of the third order with respect to the eccentricities, the inclination, and the ratio of the parallaxes; these values include all powers of the ratio of the mean motions since the numerical value of this ratio has been used. The results are given for rectangular coordinates. They also include the parts of the ratio of the mean motions, as far as these depend on the squares of the eccentricities, the inclination, and the ratio of the parallaxes. The values of the latter have been re-calculated since my paper of March 1897 * appeared, and no sensible differences from the values there given appeared. Instead of the value $-1739''\cdot6$ in the part of the motion of the perigee of the form $n\gamma^2 f(m)$ should be put $-1739''\cdot8$ (see p. 338 of the paper referred to); and for the value $-616''\cdot0$ in the part of the motion of the node of the form $ne^2 f(m)$ should be put $-616''\cdot1$ (p. 340). I may add that differences from Delaunay's values, after proper estimation had been made for the remainders of his series in powers of m, were found in the cases only of the parts of the motion of the perigee, which were of the forms $ne^2 f(m)$ and $ne'^2 f(m)$. The latter difference was found to be due to an error in Delaunay's theory, which was actually detected (*loc. cit.* pp. 340, 341). The former difference seemed to be due also to an error in Delaunay's theory in view of the three quite separate determinations which I have made, and which agree amongst themselves. If Delaunay's value had been correct, a difference from the observed value of about $26''$ in the annual motion of the perigee would have resulted. Hansen's and my values differ by less than $2''$ from the observed value. We must therefore conclude that in all probability Delaunay is in error.

These errors would naturally cause differences in the coefficients of $\sin(2iD+l)$, $(i=\pm 1, \pm 2, \ldots)$ in longitude between Delaunay's theory and mine, as far as these coefficients depend on $e^3 m^i$, $ee'^2 m^i$. I have transformed my results to polar co-ordinates

* *Monthly Notices of R.A.S.*, vol. lvii. p. 332–341.

in order to compare them with those of Delaunay. Only one difference was found which seemed to indicate an error when estimation was made for remainders in Delaunay's results, and this difference was precisely where it might have been expected, namely, in the part of the coefficient of sin $(2D-l)$, which is of the form $e^3f(m)$. The part of this coefficient, which is of the form $ee'^2f(m)$, is not carried sufficiently far in Delaunay's theory to notice any difference, as the series in powers of m converges very slowly. The part of the form $e^3f(m)$ in my theory contributes $-1''\cdot 23$; in Delaunay's theory it is $-1''\cdot 13$, or, when estimation is made for the remainder, $-1''\cdot 07$. These small differences in the values of the coefficients of the periodic terms are, of course, not very important practically, but the comparison furnishes a valuable test of the accuracy of the various calculations, and in this respect there is no cause for dissatisfaction.

The terms of the fourth order are now nearing completion, and, so far as the various tests have been able to be applied, appear to fulfil the degree of accuracy which was aimed at. They have demanded more extended calculations than the terms of any other order have required or will require. Circumstances prevent them going forward very rapidly at present; but it is hoped that they may be ready for publication within the next twelve months.

Haverford College, Pa.:
1899 *November* 3.

On the proper Motions of Berlin B, Nos. 5072 *and* 5073.
By F. A. Bellamy.

In the comparison of Plate 1415, taken at the University Observatory, Oxford, for the *Astrographic Catalogue* in 1899, R.A. $14^h\ 20^m$, $+25°$, with stars in the *Astronomische Gesellschaft* Catalogues of Cambridge and Berlin, a large discordance was noticed between the Oxford measures and two stars Nos. 5072 and 5073 in the Berlin B Catalogue.

Failing to find any notification of an error or discordance in the *Bonn Durchmusterung* or Berlin B Catalogue, or any proper motions from the usual sources of information, we were fortunate to find that another plate of this region had been taken in 1893, but rejected through insufficient number of stars.

For comparison of this plate with 1415 four stars were selected and the measured co-ordinates compared. The linear corrections for reducing plate 399 to 1415 were found to be

$$+\cdot 0083x+\cdot 0013y-\cdot 177 \text{ to } x.$$
$$-\cdot 0013x+\cdot 0083y-\cdot 046 \text{ to } y.$$

To show how quickly two plates may be compared, the actual figures are given below (in reseau intervals).

					Berlin 5075	5072	5073
Plate 399 x	14·788	12·585	23·106	1·774	16·187	15·781	15·632
$-ax$	−·122	−·104	−·192	−·015	·134	−·131	−·130
$-by$	−·003	−·033	−·016	−·020	−·002	−·003	−·003
$-c$	+·177	+·177	+·177	+·177	+·177	+·177	+·177
	14·840	12·625	23.075	1·916	16·228	15·824	15·676
Plate 1415 x	14·840	12·627	23·074	1·915	16·229	15·844	15·696
$x_{399}-x_{1415}$	−·000	−·002	+·001	+·001	−·001	−·020	−·020
Plate 399 y	2·413	25·193	12·440	15·506	1·697	2·093	2·051
$-dx$	+·019	+·016	+·030	+·002	+·021	+·020	+·020
$-cy$	−·020	−·209	−·103	−·129	−·014	−·017	−·017
$-f$	+·046	+·046	+·046	+·046	+·046	+·046	+·046
	2·458	25·046	12·413	15·425	1·750	2·142	2·100
Plate 1415 y	2·456	25·048	12·413	15·426	1·755	2·115	2·076
$y_{399}-y_{1415}$	+·002	−·002	·000	−·001	−·005	+·027	+·024

The differences for the two stars B 5072 and 5073 between the Oxford plates, which were exposed at epochs 1893·342 and 1899·400, are large, and undoubtedly due to proper motions which seem common to the two stars. From these differences annual Proper Motions of $+0^{s}\cdot070$ in R.A and $-1''\cdot26$ in Dec. were deduced; though the difference of epochs is only six years, these values may be very near the truth, as they depend solely on measures from two photographic plates, and not on meridian observations.

Using these proper motions, and carrying back the Oxford measures to the epoch of Berlin, we get the following comparison:—

			s	"
Berlin B. 5072	Epoch 1880·9.	Oxf.—Berl.	−0·07 and	+0·9
Berlin B. 5073	Epoch 1881·1.	Oxf.—Berl.	−0·04 ,,	+0·6

The region which includes these two stars has also been photographed at the Paris Observatory; and in the Report for 1895, page 18, the plate, 954, is mentioned as having been measured.

The positions for the two stars for 1900·0 from Oxford measures are

		h	m	s	°	′	″
Berlin B.	5072	14	21	5·40	+24	5	55·2
	5073	14	21	8·59	+24	6	7·5

I have not been successful in finding any observations of these two stars as a double star, probably the wide distance causing them to escape notice; moreover they are both fainter than the 9th magnitude, and possibly 5073 is slightly variable, as it is not given in B.D.—though noted as 9·1 at Berlin—unless only the brighter of the two was purposely observed. But their large common proper motion seems to show that they are physically connected. The stars deserve to have some observations made for magnitude, motion in space or about each other, and for parallax.

During the course of work for the *Astrographic Catalogue* at the University Observatory, Oxford, many occasions have arisen when plates taken in the earlier years have been of great use in checking, if not in determining, proper motions.

Had the zones $+25°$, $+27°$, $+29°$, $+31°$, been systematically photographed in the earlier period of the work, and the intermediate or overlapping zones, $+26°$, $+28°$, $+30°$, been left till the later years, we should have had at Oxford a difference of epoch of not less than five years, quite sufficient to, at least, verify proper motions. This, however, has not been done here; but, as early plates, rejected through want of stars, often become valuable for this purpose, it may be useful to bear this in mind at those observatories where the plates have not yet been taken. Dr. Gill's proposal in a recent report * to take all the plates over again for measurement seems an excellent one.

University Observatory, Oxford:
1899 *November* 22.

Since writing the above paper I have recollected that the late Radcliffe observer, Mr. E. J. Stone, published a paper † on a case somewhat analogous to this. The paper refers to the proper motions of four stars in the southern hemisphere, ζ *Toucani*, ζ^1 and ζ^2 *Reticuli*, and ϵ *Eridani*. From his discussion Mr. Stone concluded that the four stars have a common proper motion of more than $1''$, also that each star is moving away from every other star in the group, being at one time near to each other. The four stars are widely separated in N.P.D., being $2\frac{1}{2}°$, $4'$, $19\frac{1}{2}°$! respectively; and in R.A. ζ *Toucani* is 3^h ! from the other stars, giving an angular distance of $33°$!

As these four stars fall in zones photographed for the *Astrographic Catalogue* at the Cape of Good Hope and Melbourne Observatories, it is hoped that they will not be neglected, but a further discussion be made with recent material.

November 24.

* *Monthly Notices*, lix. p. 247.
† *Monthly Notices*, xl. p. 26.

New Nebulæ discovered photographically with the Crossley Reflector of the Lick Observatory. By James E. Keeler, D.Sc.

In a recent number of the *Monthly Notices* (vol. lix. p. 537) I printed a list of seven small nebulæ found on plates which had been exposed to the nebula *Messier* 51 with the Crossley reflector. At that time I considered this a rather remarkable number of nebulæ to be found on a plate covering only about one square degree, but more recent experience has shown that as many new nebulæ may generally be found on photographs taken with the Crossley reflector, and sometimes a much larger number. Thus, on a plate exposed for four hours, on November 6, to the nebula H V. 19 *Andromedæ*, there are thirty-one new nebulæ and nebulous stars; on a photograph of H I. 53 *Pegasi*, twenty; and there are nearly as many on several other plates. Besides these new nebulæ, the existence of which has been verified by independent photographs, the plates contain a considerable number of objects which are probably nebulæ so small that the resolving power of the telescope is insufficient to define them in their real form and to bring out their true character. They appear as star-discs which are less dense than true star-discs having the same diameter.

With exposures of four hours the Crossley photographs show stars and nebulæ far beyond the range of any visual telescope, though there are hundreds, if not thousands, of unrecorded nebulæ within reach of our 36-inch refractor. On the assumption that there are three new nebulæ in each square degree (a number which is much below the average for the photographs I have already taken), the number of new nebulæ in the whole sky would be about 120,000. Doubtless there are large regions where few, if any, new nebulæ are to be found; still, I am disposed to regard the above estimate as below the truth.

It is a remarkable and highly significant fact that most of the nebulæ photographed with the Crossley reflector seem to be spirals. In various cases known nebulæ have already been shown to have a spiral form by other observers. The Crossley photographs have shown that many other known nebulæ have the same structure; while in the case of a large proportion of the new nebulæ I have mentioned, a spiral form is either directly recognisable, or is rendered highly probable by the fact that the nebulæ have the same appearance as well-known spirals when photographed with a small instrument. We may perhaps regard the spiral form as that which is normally assumed by a compact isolated nebulous mass, and the exceptions (of which there are many) to somewhat unusual conditions—possibly, in part, to the absence of any definite moment of rotation for the aggregate of the particles constituting the nebula.

Lick Observatory, University of California:
1899 *November* 15.

Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

The following nebulæ have been incidentally noted during the past few months, while making measures of catalogued nebulæ with the 20-inch refractor. The positions given depend upon micrometric measures, and are for 1900·0. In the "Descriptions" and "Notes" numbers enclosed in brackets refer to Dreyer's Index Catalogue; other numbers are those of the N.G.C. :—

No.	Date.		R.A. h m s	Dec. ° ′	Descriptions.
	1898.				
1	Dec.	16	0 50 50	−10 31·6	vF, S, near 309.
	1899.				
2	Jan.	6	2 29 16	−11 28·7	eS, vF, R, prob. nebs. ✱. Near 977 and 981.
3	Mar.	14	9 22 9	−11 40·5	F, vS, 10^m ✱ p 7^s, 0′·8 n.
4	Apr.	10	10 31 20	−12 12·3	eF, eS, possibly a ✱.
5	May	11	12 43 46	−13 51·1	vF, vmE 210°, 2′ long.
6	May	10	12 45 2	−13 50·1	eF, vS.
7	May	10	12 45 9	−13 46·6	eF, vS.
8	May	10	12 45 16	−13 52·9	eF, vS.
9	May	10	12 45 23	−13 56·9 ±	eeF, vS, possibly a 14^m ✱.
10	May	11	12 46 4	−14 1·8	F, vS, R.
11	May	10	14 14 12	− 4 1·6	vF, S, mE 200°. Near (997).
	1898.				
12	Sept.	7	18 36 40	+39 56·1	eS, eF. Near 6685 and 6686.
13	Sept.	17	21 34 6	−22 51·4	vS, eF. Near 7103 and 7104.
14	Oct.	11	23 34 19	−22 58·0	vF, vS, R, 6′·5 n of Swift 234.
15	Nov.	16	23 41 10	−28 33·6	vF, vmE 200°, 20″ long.

Notes.

No. 1 precedes 309 51^s, 1′ 5 south.

No. 3 follows 2881 about a minute (of time).

No. 4 is near 3295 and 3296, which precede the places given by Leavenworth by 2^m 40^s. Leavenworth gave the same right ascension for 3295, 3296, and 3297. On 1899 April 10 I measured the places of 3295 and 3296. I could only suspect 3297. The object which I have supposed to be new follows the others 3^m 30^s.

Nos. 5–10, together with No. 15 of my former list, published in *Monthly Notices*, vol. lviii. No. 9, are in the vicinity of 4724 and 4727. I believe 4726 and 4740 to be identical at 12^h 46^m 18^s, −13° 40′·6.

No. 11 precedes (997) about 30^s. (998), which its discoverer pronounces "eeF, v diffic.," I did not see. In its position, or very near it, is a double star of mags. 13·5–13·5, distance 30″, and angle 160°.

No. 12 precedes 6685 less than 2^s, 2′·7 north. Between them lies a star of mag. 11·5.

No. 13 is in the same field with 7103, 7104 (1393), and No. 17 of my list in *Monthly Notices*, vol. lviii. No. 9. These five objects have all been seen in one night. Between my two novæ and 7103 one or two may exist, having

been suspected on more than one night. A large telescope may well deal with this group.

No. 15 has puzzled me somewhat. The southern end is the brightest portion, and at times it seems as if the object were really a very faint double star, one or both components of which are nebulous.

Observations of Nebulæ made at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

The following notes on nebulæ form a continuation of those given on pp. 515–24 of the Supplementary Number of the *Monthly Notices* for 1898. They were made during the twelve months beginning 1898 July 1 and ending 1899 June 30. During this period illness and occupation with other observations, especially upon *Eros*, have notably interfered with the regular observations of nebulæ.

The numbers given below are the current ones of the N.G.C., except those which are enclosed in brackets, which refer to the Index Catalogue in vol. li. of the *Memoirs of the R.A.S.* When the name Swift is given, followed by a number, reference is made to the list published in *A.N.* 3517. In this list Swift has collected all previous discoveries of nebulæ at the Lowe Observatory, and has numbered them consecutively. Positions of a few Marth nebulæ are given below, because those in the N.G.C. are only approximate, though they are not far astray. Data about position angles and distances found in the following notes are, in the main, not derived from measures, but from eye-estimates. I have frequently made special notes about condensations in faint nebulæ, where it has seemed that the condensations were sufficiently bright and well defined to be suitable for measures of parallax with a large telescope. All positions are referred to the mean equinox of 1900·0. The eyepiece used on the new Bruce micrometer magnifies 200 diameters, and gives a field 15′ in diameter.

As previously, all observations were made with the 20-inch Clark-Saegmuller equatorial refractor.

Swift 1. The position is $0^h\ 1^m\ 22^s$, $-4°\ 16'{\cdot}4$.

135. The position is $0^h\ 26^m\ 43^s$, $-13°\ 53'{\cdot}3$.

178. The position is $0^h\ 34^m\ 7^s$, $-14°\ 43'{\cdot}2$.

209. This may almost be called a nebulous star. Its position is $0^h\ 34^m\ 4^s$, $-19°\ 9'{\cdot}4$.

232. The position is $0^h\ 37^m\ 48^s$, $-24°\ 6'{\cdot}5$.

235. The position is $0^h\ 37^m\ 56^s$, $-24°\ 5'{\cdot}4$.

303. This is elongated at 160°. Its position is $0^h\ 49^m\ 56^s$, $-17°\ 11'{\cdot}8$.

309. The position is $0^h\ 51^m\ 41^s$, $-10°\ 27'{\cdot}2$.

333. The position is $0^h\ 53^m\ 54^s$, $-17°\ 0'{\cdot}5$.

Swift 24. This looks resolvable, and is equivalent in bright-

ness to a star of mag. 10–11. It is very small. The position is $1^h\ 43^m\ 19^s$, $-27°\ 23'·3$.

686. In the N.G.C. is the note "2 st nr." They are of mags. 7 and 8, and precede the nebula.

808. The elongation is at 200°.

921. The position is $2^h\ 21^m\ 48^s$, $-16°\ 17'·8$.

929. The position is $2^h\ 22^m\ 28^s$, $-12°\ 32'·1$.

942–3. Of this very faint double nebula the southern component is the brighter, being equivalent to a star of mag. 13. The northern is of mag. 13·5. The angle is 350°, and the distance 40″. Both have good nuclei. Their positions were given in *Monthly Notices*, vol. lviii. No. 6. On one night an eF nebula was suspected 20 seconds preceding this pair.

944. This is much elongated at 210°, and looks like a nebulous double star. The position is $2^h\ 21^m\ 54^s$, $-14°\ 58'·0$.

981. The position is $2^h\ 28^m\ 9^s$, $-11°\ 24'·9$.

989. The position is $2^h\ 29^m\ 3^s$, $-16°\ 57'·0$.

1013. This has a good nuclear brightening, and would be suitable for parallax measures with a large telescope.

1074. The position is $2^h\ 38^m\ 54^s$, $-16°\ 43'·3$.

1075. This contains a condensation of mag. 13·5. Its position is $2^h\ 38^m\ 52^s$, $-16°\ 37'·5$. It is to be noticed that 1075 really precedes 1074. The N.G.C. gives the same right ascension for both.

1151. Leavenworth queried whether this were a nebula. It seemed to me not to be stellar, as I noted it as "eF, vS."

1180 and 1181. Leavenworth gave the same right ascension for these, the southern one being 1181. It has a good nucleus of mag. 13·5. To avoid confusion the N.G.C. numbers should be retained, though 1181 really precedes 1180. The positions are:—

1180	$2^h\ 52^m\ 22^s$, $-15°\ 24'·8$.
1181	$2^h\ 52^m\ 19^s$, $-15°\ 26'.9$.

1182. The nucleus is of mag. 14. The position is $2^h\ 58^m\ 38^s$, $-10°\ 3'·7$.

1413. This is almost stellar, so faint is the nebulosity surrounding the central eS condensation. The position is $3^h\ 35^m\ 35^s$, $-15°\ 56'·0$.

1416. Muller gave this nebula as 2′ north of a star of mag. 8·6. It is really south of the star. There is another star of equal mag. about 5′ south of the star mentioned. The position of the nebula is $3^h\ 36^m\ 41^s$, $-23°\ 2'·4$

1445. The position is $3^h\ 40^m\ 9^s$, $-10°\ 10'·4$.

1486. The position is $3^h\ 51^m\ 57^s$, $-22°\ 6'·7$.

1547. Leavenworth queried whether this were a cluster. I had no such suspicion. The southern end is the brightest portion. The position is $4^h\ 12^m\ 44^s$, $-18°\ 6'·3$.

1561–5. In my communication in *Monthly Notices*, vol. lvii No. 9, it was stated that I could not see all these nebula I have finally, however, been able to find and measur nebulæ which correspond to Leavenworth's descriptions o those in this group. His positions are sufficiently erroneou to warrant the publication of the correct places. To thi group I have added one new nebula, the place of whicl was published on p. 523 of vol. lviii. of the *Monthl Notices*. I suspect another eF nebula near 1565. It estimated position is $4^h\ 18^m\ 54^s \pm$, $-15°\ 55' \pm$. Th positions are as follows:—

	h	m	s	°	′
1561	4	18	28,	−16	4·7
1562	4	17	15,	−15	59·5.
1563	4	18	21,	−15	57·9.
1564	4	18	28,	−15	58·3.
1565	4	18	51,	−15	58·6.

It is to be noted that 1562 precedes the rest of the grou over a minute. According to Leavenworth it is brighte than 1563, 1564, or 1565; no nebula brighter than thes exists in the place given by Leavenworth for 1562. A usual, Leavenworth's declinations are much closer to th truth than his right ascensions.

1650. Two nebulæ were suspected near this, one n and the other sf, at distances of about 3′. The n one is probably only two eF stars. The position of 165 is $4^h\ 40^m\ 40^s$, $-16°\ 3'·2$.

1821. The elongation is at 300°. The position is $5^h\ 7^m\ 14^s$ $-15°\ 15'·4$

Swift 80· Swift says: "bet 2 stars p and f." I see no star in this position relative to the nebula, which are suffi ciently near to aid in identifying it. The position i $5^h\ 27^m\ 52^s$, $-17°\ 17'·7$.

2139. For this I searched on two nights unsuccessfully though H calls it only "F." I believe it to be identica with Swift 90, which is about 10′ north, and 25^s fol lowing.

Swift 90. This seemed to me to be fainter and smaller thar the description "B, L" would indicate. The position ha been given in *Monthly Notices* lviii., No. 9.

Swift 91. This is bush-like, and seems to contain a star o mag. 14. The position is $6^h\ 1^m\ 22^s$, $-27°\ 50'·9$.

2263. The two stars mentioned by h are of mags. 11·5 and 12, and lie respectively north and south of the nebula at distances of, roughly, 2′, slightly following. Another sta of mag. 11·5 follows the nebula 1′·7, and is 0′·3 north.

2283. This curious object, discovered by H, is a smal quadrilateral of stars of mags. 11, 12, 11 and 13, the in terior of which is nearly filled by an eF nebulosity, in

which there is a condensation of mag. 14. This condensation lies at about the middle point of the sp side of the quadrilateral.

Swift 92. This is in a pretty rich field of faint stars. In the centre of the nebula is a condensation of mag. 13.

2612. h calls this "B." I make it only F. The elongation is at 100°. The two stars mentioned by h are of mags. 10 and 11. The brighter star lies $1'·2$ nearly due south of the nebula. The fainter is nearer, north, and a little following.

2674. For this I have hunted on two nights in vain. Stone describes it as "eF, S, neb. ?"

2706. The elongation is at 170°, the nebula being about 1′ long and one-fourth as broad. The neighbouring star noted by Swift is of mag. 9, and follows 5^s, $0'·5$ south.

2757. Muller queried whether this eF object were a star. The longer I looked at it the more positive I became that it was a double star of mags. 14, angle 45°, and distance 12″.

2811. This has a small bright centre, with faint wings at angles of 210° and 30°, and reminds one of the great nebula in *Andromeda*.

2821. At times this seemed to have a nucleus of mag. 13·5. h speaks of a "✱ 11 att." It is np the nebula, and I saw no connection between them.

2881. The two stars mentioned by Swift are of mags. 9·5 and 10·5, and are sf the nebula.

Swift 95. The two stars mentioned by Swift are of mags. 9 and 9·5. The brighter follows the nebula 3^s, $1'·3$ south. The fainter stands at a position angle of 60° with reference to the brighter, and is about $1'·5$ distant from it. The position is $9^h\ 31^m\ 16^s$, $-11°\ 59'·4$.

3030. The position is $9^h\ 45^m\ 18^s$, $-11°\ 45'·4$.

3058. The following nucleus is the brighter. The preceding is at 210°, 20″. The position of the brighter nucleus is $9^h\ 48^m\ 44^s$, $-12°\ 0'·7$.

3113. The nebula follows the two stars of mag. 8 mentioned by h as forming a triangle with it. The triangle is rudely equilateral. The nebula is eF and vL, but seems to have one spot a trifle brighter than the rest.

3280 and 3295. I found nothing in the N.G.C. position for 3295. But a nebula which corresponds to Leavenworth's description was found less than 3^m preceding, at nearly the N.G.C. declination. It involves a wide double of mags. 13·5, distance 30″, and angle 70°. 3280, discovered by Common, has a description similar to that of 3295. As the positions of Common's nebulæ are not very accurate, I judge 3280 and 3295 to be the same. The position is $10^h\ 27^m\ 48^s$, $-12°\ 7'·3$.

3296. The large error of the N.G.C. right ascension of this

object is almost exactly the same as the corresponding error for 3295, which was discovered by the same observer. The position of 3296 is $10^{h}\ 27^{m}\ 50^{s}$, $-12^{\circ}\ 12'\cdot1$.

Swift 112. The doubles mentioned by Swift are very wide, and the average magnitude of the stars in them is 11. They are np and sf the nebula. Swift probably made an error of $15'$ in reading his declination circle for this object. The position is $10^{h}\ 31^{m}\ 19^{s}$, $-23^{\circ}\ 48'\cdot3$.

3704. I have now hunted in vain for this object on four nights, widely separated. On each night I measured the position of its neighbour 3707, which is supposed to be of the same order of brightness, and which is not at all difficult to see. Both are Tempel nebulæ.

3777. The position is $11^{h}\ 31^{m}\ 3^{s}$, $-12^{\circ}\ 0'\cdot8$.

3831. h calls this "R," while I find it to be elongated at 200°.

3969. This I was unable to find in the N.G.C. place. But about $10'$ further south I found one answering to its description, except that Stone notes "✱ 10 np $4'$," while I see a star of mag. 8·5 nearly north. The stellar point in the centre of the nebula is of mag. 14. The position is $11^{h}\ 50^{m}\ 3^{s}$, $-18^{\circ}\ 22'\cdot2$.

Swift 131. The elongation is at 120°.

4225. H. says, "✱ 170°, $60''$." The star referred to is of mag. 8·5, follows the nebula $0^{s}\cdot6$, and is $1'\cdot6$ south of it.

4279. Swift rates this at the same brightness as 4280. But I could not find it on either of two nights, though it is supposed to be close to 4280 and 4285, both of which I saw. There is nothing there comparable in brightness to 4280 and 4285.

4285. This was noted on one night as fainter and smaller than 4280. On another night it was called "much fainter" than 4280. But Swift describes it as brighter.

4361. This has a vB sharply defined eS nucleus of mag. 9·5. On account of moonlight I could not see much surrounding nebulosity.

Swift 138. The star of mag. 7 mentioned by Swift follows the nebula 18^{s}, $2'\cdot6$ north. The position of the nebula is $12^{h}\ 19^{m}\ 44^{s}$, $-25^{\circ}\ 28'\cdot6$.

4484. The N.G.C. right ascension of this seems to be 2^{m} in error. The position is $12^{h}\ 23^{m}\ 43^{s}$, $-11^{\circ}\ 5'\cdot9$.

Swift 143. The position is $12^{h}\ 44^{m}\ 42^{s}$, $-25^{\circ}\ 22'\cdot6$.

4724, 4726, 4727, and 4740. In my communication in *Monthly Notices*, vol. lviii. No. 9, I mentioned the region in which these lie as needing exploration with a large telescope because of the errors in the places of 4726 and 4740. A larger telescope than mine might show many more nebulæ in this group. The results of my work on three nights are as follows:—The N.G.C. positions of 4724 and 4727 are practically correct. I can find nothing

in the N.G.C. place for 4726. On two nights I measured the position of an object which I assume to be 4726: it is at $12^h\ 46^m\ 18^s$, $-13°\ 40'{\cdot}6$. I cannot see anything in the N.G.C. place for 4740. Under date of 1899 August 9 Dr. Swift writes, in reply to a query: "I have examined the record of 4740, and find that it was made 1887 April 27, with position $12^h\ 46^m$, $-13°\ 41'$. The right ascension is for 1890, the declination for date of discovery. I have no recollection about it." This position agrees so well with that of 4726 that I assume them to be identical.

I have discovered in this vicinity seven objects supposed to be new. Their descriptions and positions follow:—

The first Nova is vF, vmE 210° 2′ long. The position of its brightest part is $12^h\ 43^m\ 46^s$, $-13°\ 51'{\cdot}1$.

The second Nova is eF, vS: its position is $12^h\ 45^m\ 2^s$, $-13°\ 50'{\cdot}1$.

The third Nova is eF, vS: its position is $12^h\ 45^m\ 9^s$, $-13°\ 46'{\cdot}6$.

The fourth Nova is eF, vS: its position is $12^h\ 45^m\ 16^s$, $-13°\ 52'{\cdot}9$.

The fifth Nova is eeF, vS. Possibly it is only a star of mag. 14. It precedes the sixth Nova by 15^s, at nearly the same declination. Its position therefore is $12^h\ 45^m\ 23^s$, $-13°\ 56'{\cdot}9\pm$.

The sixth Nova is vF, vS, R, 0′·6 n of star of mag. 11. Its position is $12^h\ 45^m\ 38^s$, $-13°\ 56'{\cdot}9$.

The seventh Nova is F, vS, R: its position is $12^h\ 46^m\ 4^s$, $-14°\ 1'{\cdot}8$.

4792. While measuring 4794 I hunted for this, which Tempel calls "vS, R, 7′ nnp 4794." I could not be sure of it. Possibly it is a suspicious-looking star of mag. 11.

4794. The nebula contains a condensation of mag. 13. The brightest of the stars mentioned by H is of mag. 9·5, and follows the condensation $1^s{\cdot}2$, 3″ north. This star appears to be close to the nf border of the nebula.

5420. The position is $13^h\ 58^m\ 36^s$, $-14°\ 8'{\cdot}1$.

Swift 168 and 169. Probably these are identical with (997) and (998). I examined the region on one night only, and saw only a very faint double star in or near the place of (998).

6230. This nebula is accompanied by a star of mag. 13, at a distance of 10″ and angle of 160°.

6235. In the N.G.C. this is given as "r r r, st 14–16." I examined it when the seeing was excellent. The brightest star is of mag. 12, and is in the np end. The object seems nebulous, but contains a number of very faint stars. Possibly the nebulous-appearing background is composed simply of minute stars, but it impressed me as truly nebulous.

6284 and 6287. The N.G.C. descriptions of these differ but

little. Each is described as a cluster. I examined them on the same night, and noted that 6284 was probably a nebula, while 6287 seemed to be a cluster. Perhaps greater optical power is necessary for a decision.

(1247). This nebula of Bigourdan's I was unable to find. 30^s preceding the place given in the Index Catalogue there is a double star of mags. 12—12, distance 3″ and angle 270°.

6369. In this annular nebula the centre is much darker than the periphery. The brightest part is in the np portion of the ring. The faintest part is in the sf portion of the ring.

6432. This "cluster" contains only four stars, two of mag. 12 and two of mag. 13.

6445. The appearance of this is remarkable. It is somewhat bullet-shaped. The sf end seems to be cut almost straight across, the position angle of its direction being 70°. The brightest part of the nebula is in the np end. The middle is much fainter than the ends.

6449. In this are two or three stellar points.

6450. This was searched for unsuccessfully on two good nights.

6465. Search was made for this on two nights. On the first no nebula could be found. On the second it was discovered that, instead of a nebula, there are simply two doubles of mag. 12. In each pair the distance is 4″, and the two pairs are 15″ apart.

6530. In the N.G.C. this is described as following 6523. It is really involved in faint nebulosity on the borders of 6523.

(1271). An examination on two nights led to the conclusion that it is simply an eF extension of 6523.

6544. In the N.G.C. this is called "r." I examined it on two nights. It evidently contains several stars. On the first night it was noted that "the apparent nebulosity may be due to faint stars." On the second night, when the definition was fine, the following note was made: "Object looks exclusively starry." If these observations are correct it is simply a faint cluster.

6551. Here I see simply a few stars of mag. 13.

(1274). Here is a nebulous region looking like a thin veil over the sky.

6556. I see nothing in the entire region except thousands of the minutest stars.

6559. The nebula itself is very faint and formless. The brightest star in it is of mag. 8·5, and has a 10·5 mag. companion at a distance of 6″ and angle of 190°.

6589. The double star mentioned by Swift as involved in the nebula is of mags. 13-13, and has a distance of 20″, with an angle of 210°. 5^s preceding the nebula is another

double of mags. 9–11·5, having a distance of 30″ and an angle of 225°.

6593. This is eS, and about as bright as a star of mag. 12. Very little nebulosity is visible.

6616. The "2 F st nr" are of mags. 9 and 10 respectively. The brighter precedes the nebula 2^s, 0′·6 south. The position is $18^h\ 13^m\ 28^s$, +22° 12′·0.

6618. This contains many very faint stars; changes of brightness in different parts are very abrupt. Dark "holes" are near by. The brightest part is small, elongated at about 165°, and contains some extremely faint stars. A magnificent object.

6642. The outskirts of this can be resolved. The bright centre I think to be stellar.

6660 and 6661. A careful examination of this region confirms Pechüle's statement that they are identical. The correct position is $8^h\ 30^m\ 25^s$, +22° 49′·8.

6814. This has a nucleus of mag. 13.

6822. On two nights I called this "vS," while Barnard, who discovered it with a 6 inch refractor, called it "L."

(1308). A double star follows 5^s, 40″ south. It is of mags. 9–12, distance 6″, and angle 150°.

6836. In this nebula, or just on its f edge, is a star of mag. 13·5, apparently not noticed by its discoverer.

Swift 185. The three stars mentioned by Swift are of mags. 9·5, 10, and 9, and are about 8′ south of the nebula. Their line prolonged does not strike the nebula, but follows it a little. The position is $19^h\ 50^m\ 10^s$, −37° 35′·6.

Swift 186. The position is $19^h\ 53^m\ 32^s$, −38° 50′·9.

Swift 187. The position is $19^h\ 54^m\ 10^s$, −38° 50′·8.

6903. h calls this "cL"; I observed it on one night, and noted it as "eS."

(1324). The position is $20^h\ 26^m\ 48^s$, −9° 23′·6.

(1325) and (1326). I am inclined to the opinion that these two Swift nebulæ are identical with two which Marth found with the 4-foot Lassell reflector, mounted at Malta, and which are Nos. 6928 and 6930 respectively in the N.G.C. Marth seems to have discovered these, as well as 6927, on the same evening, and afterwards verified them. It appears improbable that Swift, who makes no mention of seeing Marth's nebulæ, has discovered two close by them, which I did not see. A star of mag. 11 is just nf 6928, and a double star of mags. 12, and distance 5″ follows 6928 by 20^s, 0′·7 north. The positions are:—

6928, $20^h\ 28^m\ 1^s$, +9° 35′·2
6930, $20^h\ 28^m\ 10^s$, +9° 32′·0

When observing these objects I was unaware of the existence of 6927, which is much fainter, and which I did not see.

Swift 203. The position is $20^h\ 59^m\ 3^s$, $+11°\ 22'.0$.

(1368). Swift calls this round, but I find it to be much elongated at 225°.

7105. On three nights I failed to find this. On the third night I noted in its vicinity a double of mags. 13–13, distance 8″, and angle 210°. This might be 7105, except that Leavenworth estimated the elongation of his at 130°.

7112. A search on two nights failed to reveal this.

Swift 207. The position is $21^h\ 41^m\ 25^s$, $-35°\ 20'.8$.

Swift 208. The position is $21^h\ 42^m\ 20^s$, $-35°\ 24'.9$.

7135. In the N.G.C. is noted a "* 14 att. p." This is of mag. 12, and precedes 2^s. Another star of like brightness is involved in the nebula near its northern border. I judge this to be identical with Swift 209. The object which I saw answers to both descriptions.

7152. According to the N.G.C., Lassell did not succeed in finding this. It is a small, exceedingly faint, and diffuse stain on the sky.

7157. In the N.G.C. we read for this object, "BD*p 8^s." There is no bright double star in the vicinity, and I could find no nebula. Possibly, however, the abbreviation "BD" is here used for "Bonn Durchmusterung." Spitaler also failed to find this.

7158. This nebulous star is of mag. 13. It may be double at 270°. The position is $21^h\ 52^m\ 6^s$, $-12°\ 4'.1$.

7165. This nebula contains a condensation of mag. 13.

7188. The position is $21^h\ 57^m\ 57^s$, $-20°\ 48'.1$.

7214. h calls this a globular cluster. To me it appeared to be a nebula having a nuclear condensation of mag. 12; the surrounding nebulosity was indefinite in extent.

7247. The position is $22^h\ 12^m\ 7^s$, $-24°\ 13'.8$.

7252. This is small and pretty faint, but has a good nucleus.

Swift 213. The position is $22^h\ 17^m\ 4^s$, $-19°\ 22'.4$.

Swift 214. The position is $22^h\ 17^m\ 16^s$, $-19°\ 23'.1$.

7287. This is a double star of mags. 11·5–11·5, distance 6″ and angle 150°. The seeing was poor when I examined it; I could not see any nebulosity connected with it. The right ascension given in the N.G.C. is about 2^m too large.

(1447). The position is $22^h\ 24^m\ 48^s$, $-5°\ 38'.0$.

7294. The position is $22^h\ 26^m\ 36^s$, $-25°\ 54'.7$.

7300. In the N.G.C. this is called "cS." There is, however, considerable outstanding nebulosity which entitles it to the appellation "pL." The elongation is at 150°.

7310. The position is $22^h\ 29^m\ 9^s$, $-23°\ 0'.0$.

7313. The position of this Marth nebula is $22^h\ 30^m\ 0^s$, $-26°\ 37'.1$.

7314. This is roughly estimated to be 2′·3 in length, and 0′·8 broad, the elongation being at 0°. There is a condensation of mag. 12 below the middle, near the preceding

edge. This condensation looks just like a star, and probably should be thus denominated.

7351. Swift calls this "R," but to me it appeared much elongated at 180°.

7359. The right ascension given in the Notes at the end of the Index Catalogue, and also that in the N.G.C., are erroneous. The nebula has a central condensation of about 11·5 mag., which is a trifle elongated. The position is $22^h\ 39^m\ 21^s$, $-24°\ 12'·8$.

7365. The position is $22^h\ 39^m\ 47^s$, $-20°\ 28'·6$.

7399. The position is $22^h\ 47^m\ 25^s$, $-9°\ 47'·9$.

7413. The position is $22^h\ 50^m\ 4^s$, $+12°\ 41'·4$.

(1461). I could find nothing in the N.G.C. place for this. But 10′ farther north there is a nebula corresponding fairly to Swift's description. It is, however, eS, being almost stellar, and of about mag. 12. I judge this to be Swift's object. Its position is $22^h\ 53^m\ 37^s$, $+14°\ 38'·3$.

7452. I suspected another nebula preceding this about 15^s, but the atmospheric conditions were not of the best.

7494. The position of this Marth nebula is $23^h\ 3^m\ 36^s$, $-24°\ 54'·7$.

7498. The position of this Marth nebula is $23^h\ 4^m\ 35^s$, $-24°\ 58'·0$.

7513. The position of this Marth nebula is $23^h\ 7^m\ 51^s$, $-28°\ 54'·0$.

7520. On two nights I have searched for this nebula of Tempel's without success.

Swift 229. In Swift's first list of nebular discoveries made at the Lowe Observatory, which one may find in No. 388 of the *Astronomical Journal*, this nebula is put at −18° of declination. In his later long list in *A.N.* 3517, the declination is given as −19°. I have found an object agreeing with his in description at $23^h\ 21^m\ 5^s$, $-18°\ 30'·3$. This place differs from the one in the *Astronomical Journal* by 5^s in right ascension and 5′·7 in declination. In *A.N.* 3517 the description says, "F ✻ p close nf." In the *Astronomical Journal* the star is said to *precede*. The object which I observed had a star of mag. 10 preceding it 3^s, 0′·6 north. [*Note.*—Dr. Swift has just looked up his original record for me; it is now evident that both the *Journal* and *Nachrichten* were wrong, and that the object which I found was really Swift 229.]

Swift 231. The position is $23^h\ 24^m\ 17^s$, $-29°\ 23'·0$.

7719. The position is $23^h\ 32^m\ 49^s$, $-23°\ 31'·6$.

Swift 234. The position is $23^h\ 34^m\ 9^s$, $-23°\ 3'·1$.

7730. On two nights I searched for this nebula, which Tempel called "pB, pL," but I could not find it.

(1505). The position is $23^h\ 36^m\ 29^s$, $-4°\ 7'·1$.

Swift 236. The position is $23^h\ 42^m\ 2^s$, $-28°\ 30'·7$.

Swift 237. The position is $23^h\ 42^m\ 16^s$, $-28°\ 39'·8$.

Swift 238. The position is $23^h\ 42^m\ 16^s$, $-28°\ 41'\cdot4$.

Swift 239. This is binuclear, at an angle of 250°, with a distance of 20″. The position is $23^h\ 42^m\ 33^s$, $-28°\ 41'\cdot7$.

7807. The position given by Stone is $23^h\ 56^m\ 33^s$, $-19°\ 19'\cdot6$. The position found by me is $23^h\ 55^m\ 19^s$, $-19°\ 23'\cdot8$. On one good night I looked carefully in the place given by Stone and saw no nebula.

The Bruce Micrometer of the Chamberlin Observatory. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

Through the liberality of Miss Catherine W. Bruce, of New York City, a micrometer adapted to observations of $\Delta\alpha$ and $\Delta\delta$ was built some eighteen months since for the Chamberlin Observatory, by Saegmuller, of Washington, D.C. It was especially intended for work on faint nebulæ. Each nebula is tied to some small star near at hand by micrometric measures of $\Delta\alpha$ and $\Delta\delta$. On some ensuing night, when the Moon obliterates most nebulæ, the comparison star is connected by chronographic and micrometric observations with a catalogued star. The instrument has also been used for a long series of observations of *Eros*, and for similar work on some faint comets. So excellent has been its performance, and so efficient is it for rapid work, that I have been asked by a visiting astronomer to write a detailed description of it.

1. Such a micrometer is usually screwed on to the tail-piece of the equatorial. Whenever it is taken off and replaced, a new value of the parallel, and hence of the zero of the position-circle, must be obtained. The Bruce micrometer slides off, so that when it is put back, the zero of the position-circle is the same as before. The slipping piece, on which the micrometer slides into place, is screwed on to the tail-piece in the usual way, and is fastened by three small steel screws, so that it will not work loose. When the micrometer has been slid into place it is secured by two thumb-screws. The plane in which the sliding takes place is perpendicular to the sight-line of the telescope, and the edges of the run-way are parallel to the declination axis of the equatorial.

2. The position-circle is 9 inches in diameter, and furnished with a system of solid and accurately adjustable stops by which the box can be turned precisely 90° when micrometric measures of $\Delta\alpha$ and $\Delta\delta$ are being made, without reading the graduated circle. If it is desired at any time to have the micrometer box rotate freely, as in measures of double stars, the stops can be thrown back in a few seconds, and when needed again can be swung with equal facility into their former positions. If the box be turned till it is brought up against a stop several times in succession, and the position-circle be read each time, the readings

will not differ a minute of arc. The circle can be clamped at any angle and a tangent screw used.

3. The eye-piece is swiftly movable a good distance both in right ascension and in declination, so that exceptionally long spider webs can be used. The right ascension wires are eleven in number, the central wire being flanked by two sets of five wires each. In each set the equatorial intervals are 3, 4, 4, and 3 seconds. From the central wire to the nearest of each flanking set is 10 seconds. The entire breadth of this wire system is therefore 48 seconds. By this arrangement three deliberate bisections of an object can be made with a declination wire while it is passing through the field of view, in addition to ten chronographic observations of time. The mean of the times of the bisections in declination is practically the same as the mean of the chronographic times.

The declination wires are nine in number; they are symmetrically spaced; the intervals of the four wires on one side of the central wire are 3′, 2′, 5′, and 5′. The total angular space spanned by the declination wires is therefore 30′. The entire system of declination wires is movable 10′ each side of its central position by the micrometer screw. Thus differences of declination exceeding 30′ may be measured without turning the micrometer screw much. In the hundreds of observations which have so far been made between two objects, one of which was a catalogued star, very few measures of $\Delta\delta$ have exceeded 20′.

The box is provided with an index, so that it may be placed in the centre of its run at any time. So accurately have the spider webs been put in that when the box is in the centre of its run the point of intersection of the two central webs remains upon a star, while the box is being turned through 180° in position angle.

4. For rapid work a coarse micrometer screw, having only twenty threads to the inch, has been considered essential. The screw has three large and boldly divided heads, two of which are movable. Each of the movable heads is furnished with an efficient clamp, which brings no perceptible side-strain on the micrometer screw. If three declination bisections are to be made as a star drifts through the field of view, the two movable heads are first set so that their readings agree with that of the fixed head. When the first bisection has been made, the outer head is clamped. After the next bisection the second head is clamped. For the third and final bisection no clamping is necessary. When the star has passed out of sight the three readings of the micrometer heads are noted. Even when the difference of right ascension of two equatorial stars is only a minute, ten observations of $\Delta\alpha$ and three of $\Delta\delta$ can be made without undue haste. These involve twenty chronographic registrations and six bisections in declination. When the two objects are only a few seconds apart in right ascension, the declination observations are usually made with the driving clock running.

5. The illumination of each set of wires is effected by two electric lamps of 2 c.p. each, and of about 5 volts. The lamps are so well encased that no stray light bothers the observer. They ordinarily glow with only a fraction of 1 c.p. apiece, and their intensities are so regulated by two rheostats and two mechanical shutters that any required intensity of light may be thrown on each set of wires at any time. In observing a very faint comet or nebula, it is sometimes of advantage to be able to turn the illumination in declination off and on instantaneously, or to have the two sets of wires simultaneously lighted up with different intensities. The lamps are fed by a current from a little transformer, which can be adjusted to any voltage required by them. Through the primary coil of the transformer the regular house-current of 50 volts runs. A four-point switch on the micrometer enables the observer to throw the light on the two verniers of the position-circle or on either set of wires, or on both sets simultaneously.

On the Relation between Magnetic Disturbance and the Period of Solar Spot Frequency. By William Ellis, F.R.S., formerly of the Royal Observatory, Greenwich.

Having in previous papers * compared the variations of diurnal magnetic range with the period of solar spot frequency, I have since given some attention to the relation of magnetic disturbance to solar spot frequency, comparing, as before, results derived from the photographic magnetic records, for so many years maintained at the Royal Observatory, Greenwich, with the corresponding values of sun-spot frequency as tabulated by the late Dr. Rudolf Wolf, of Zürich. Before, however, describing what has been done in this respect, it may be well to make brief reference to some conclusions arrived at in the previous papers.

Magnetic variations, as registered from day to day, include principally the effects of two distinct phenomena : (1) the solar diurnal variation, a local phenomenon which, although everywhere existing, has distinct relation to the local day ; and (2) the apparently irregular magnetic disturbance, a phenomenon of more cosmical character, since when considerable, as in magnetic storms, it is felt simultaneously over widely separated districts of the Earth's surface, the commencement of disturbance when abrupt, as is frequently the case, being absolutely simultaneous at all places, so far as the contracted time scale used in photographic registers will allow us to determine. Magnetic disturbance is not always present ; some days are altogether free from magnetic irregularity, exhibiting only the ordinary diurnal movement, but on other days magnetic irregularity, superposed

* *Phil. Trans.* for 1880, p. 541, and *Proc. Royal Society*, vol. 63, p. 64.

on the diurnal movement, exists to a lesser or greater extent. In the papers referred to I have shown the close relation that exists between the variation of diurnal magnetic range and the period of solar spot frequency, the diurnal range during the years 1841 to 1896, as recorded at the Royal Observatory, Greenwich, being, both in declination and horizontal force, greatest when sun-spots are at a maximum, and least when sun-spots are at a minimum, the irregularities in both phenomena being distinctly similar, not only as regards variation in the length of successive periods (maximum to maximum or minimum to minimum), but also in the degree of intensity at the different epochs of maximum effect.

The diurnal range compared with sun-spot frequency during the period mentioned was the monthly mean diurnal range as found by employing all days of observation, including disturbed days (omitting only a few of extreme disturbance). It was, however, further shown that if quiet days are alone employed—that is, days free from magnetic irregularity—the resulting values of mean diurnal range were altogether similar, in that in both cases there was the same marked variation in value concurrent with the variation in sun-spot frequency.*

There are necessarily considerable differences in the magnitude of the diurnal range on adjacent days when disturbance is present, and the explanation of the comparatively small effect that the inclusion of days of such character produces in mean values appears to be that irregular disturbance acts sometimes to increase and sometimes to decrease the value of the magnetic element, these opposite effects tending in the aggregate to neutralise each other to such an extent as to influence the resulting diurnal range in a minor degree only as compared with the very considerable variation in value between the epochs of minimum and maximum of sun-spots. The circumstance that the variation of diurnal range with variation of sun-spot frequency exists in a similar marked degree whether days of disturbance are or are not included shows that the variation observed is essentially that of the undisturbed solar diurnal range. Otherwise the increased range observed at epochs of sun-spot maximum might be supposed to be in a measure due to the influence of the magnetic disturbance at such epochs prevalent.†

* The mean diurnal range of declination on days of quiet magnetism was for the year 1889 (near sun-spot minimum). 6'·45, and for 1893 (near sun-spot maximum) 10'·13. The corresponding values found by using all days were 6'·67 and 10'·40 respectively, the ratio between the two numbers being in both cases the same. Similarly also for horizontal force. See the *Report of the British Association Committee on Comparing and Reducing Magnetic Observations* for 1898, p. 106.

† To persons not having had the opportunity of examining a collected series of photographic magnetic registers it would probably create surprise to see how strongly marked is the difference in the character of the records at sun-spot maximum and sun-spot minimum; as, for instance, between the records for the years 1870 and 1879. Without measurement or calculation the difference is evident to mere inspection, not only in the abundance of

Having recapitulated so much as is necessary to show that the variation of diurnal range with variation of sun-spots appears to be one independent of the effect of magnetic disturbance, we can now proceed to consider what may be really the relation of magnetic disturbance itself to sun-spot frequency. Regular magnetic observations were commenced at Greenwich in 1841; but the records for the years 1841 to 1847, depending mainly on two-hourly eye observations, although sufficient for dealing with the question of diurnal range, do not give that continuous record necessary for the present purpose. But photographic registration was commenced in the year 1848, enabling us to employ here the records for the fifty years 1848 to 1897. I would here gratefully acknowledge the kindness of the Astronomer Royal in permitting me to use the Royal Observatory records in this inquiry, and would also add that, for any opinions herein expressed or conclusions drawn, I am alone responsible.

To make any complete or extensive discussion of magnetic disturbance through a long period would be an extremely laborious task. And my object being simply to compare the frequency of magnetic disturbance with sun-spot frequency, I have contented myself with an endeavour to bring out the main features of the frequency of different degrees of magnetic disturbance, and even what I have attempted has proved to be a considerable piece of work. But a similar presentation of the characteristics of disturbance in the direction mentioned has not, I think, been before made.

As a measure of the frequency of magnetic disturbance I have counted up the number of days on which during any part of the twenty-four hours (of the astronomical day, reckoning from noon), magnetic movement or disturbance of sudden or transient character, either in declination or horizontal force, reached a stated amount, dividing the days for this purpose into five classes, according to magnitude of disturbance. In this classification any day on which was recorded one irregularity coming within the stipulated limits, either in declination or horizontal force, was included but usually there would be on the same day other similar irregularities. This system of selection, admittedly of arbitrary character, if open to criticism, nevertheless brings out some interesting distinguishing features in regard to the behaviour of magnetic disturbance. That the interpretation of the records should be similar was here more important than absolute accuracy of classification. In order, therefore, to secure, as far as possible, comparative results—since different persons might vary in their methods of applying a given rule of selection—the whole selection was made by myself, according to the annexed scheme. Class I. includes all days free from magnetic irregularity, showing only the ordinary diurnal movement:—

disturbance in 1870 and its paucity in 1879, but also in the sensibly greater boldness of the diurnal curve in the former year on days of quiet magnetism.

Class.	Degree of Disturbance.	Greatest recorded Magnetic Movement. Declination.	Horizontal Force. c.g.s. value × 10^5.
I.	None	No magnetic irregularity in either element.	
II.	Minor	Less than 10′	Less than 50.
III.	Moderate	Greater than 10′ less than 30′	Greater than 50. less than 150.
IV.	Active	Greater than 30′ less than 60′	Greater than 150. less than 300.
V.	Great	Greater than 60′	Greater than 300

60′ in declination is approximately equivalent in horizontal force to 300 (c.g.s. value × 10^5).

In Table I. there is given for each quarterly period during the years 1848 to 1897 the number of days of each degree of disturbance, according to the convention described. In dividing the year into quarterly periods defined by calendar months (January, February, and March being taken as the first quarter, and so on), a little inequality is introduced in dealing with sums instead of means, owing to the slightly different length of the several quarters which contain 90, 91, 92, and 92 days respectively (February 29 being for convenience altogether omitted, nothing unusual having occurred on this day in the different leap years included); but, remarking the very considerable variation in the successive numbers of the table, the slight inequality in the length of different quarters is immaterial. On occasions of defective or deficient photographic register at Greenwich reference was made to those of the Kew Observatory, with the kind permission of the Superintendent, the late Mr. G. M. Whipple. On some similar occasions in the earlier years the degree of disturbance was estimated from eye observations.

TABLE I.

Number of Days of Magnetic Disturbance of Different Degrees of Intensity in Quarterly Periods during the Years 1848 *to* 1897, *as deduced from the Records of the Royal Observatory, Greenwich.*

(The quarters of the year, indicated by the figures 1 to 4, are taken in the ordinary way, the first quarter comprising the months of January, February, and March, and so on.)

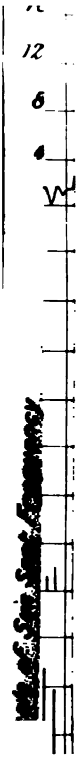
Year.		None.	Minor.	Moderate.	Active.	Great.	Year.		None.	Minor.	Moderate.	Active.	Great.
		Degree of Disturbance.							Degree of Disturbance.				
1848	1	9	50	24	6	1	1850	1	20	53	16	1	...
	2	16	51	22	2	...		2	8	69	14	...	...
	3	20	58	13	1	...		3	10	71	11	...	...
	4	7	54	23	6	2		4	23	61	8	...	...
1849	1	9	63	16	2	...	1851	1	16	58	13	3	...
	2	10	69	12	...	...		2	10	75	6	...	...
	3	7	63	22	...	...		3	7	65	14	4	2
	4	11	61	15	5	...		4	4	62	21	3	2

Year.		Degree of Disturbance. None.	Minor.	Moderate.	Active.	Great.	Year.		Degree of Disturbance. None.	Minor.	Moderate.	Active.	Great.
1888	1	7	51	31	1	...	1893	1	14	46	30	...	...
	2	3	61	26	1	...		2	13	62	15	1	...
	3	4	60	28	...	...		3	7	63	20	2	...
	4	5	60	27	...	...		4	10	57	24	1	...
1889	1	14	60	16	...	...	1894	1	6	50	27	5	2
	2	8	74	9	...	...		2	3	60	28	...	...
	3	12	60	19	1	...		3	3	65	20	2	2
	4	3	62	25	2	...		4	7	61	23	1	...
1890	1	14	63	13	...	...	1895	1	7	52	30	1	...
	2	14	75	2	...	...		2	3	64	24	...	...
	3	9	72	11	...	...		3	7	63	22	...	...
	4	6	73	13	...	...		4	7	55	30	...	...
1891	1	13	52	25	...	...	1896	1	2	44	42	2	...
	2	8	57	23	3	...		2	7	65	17	2	...
	3	9	56	27	...	...		3	9	64	19	...	...
	4	9	52	30	1	...		4	18	57	16	1	...
1892	1	...	41	42	3	4	1897	1	15	51	23	1	...
	2	11	50	24	5	1		2	9	61	20	1	...
	3	4	45	37	4	2		3	13	68	11	...	...
	4	5	49	36	2	...		4	9	61	20	2	...

The division into quarters adopted in this table tends to elimination of the influence of the seasonal inequality that, according to Table II., appears to exist.

The numbers of Table I., indicating in each class the frequency of a given degree of disturbance, are represented graphically on Plate 4. The scale of days is of equal length on the paper for the groups of no disturbance, and those of minor and moderate disturbance, but is quadrupled in length for the groups of active and great disturbance; since the number of days in these two divisions being comparatively few, the variation in number would not otherwise have been readily perceived. Above these representations of different degrees of magnetic disturbance, there is added the corresponding curve of sun-spot frequency plotted from Wolf's monthly values, derived directly from observation, as given in his *Astronomische Mittheilungen*, No. 50, and other succeeding numbers.

Examining the plate, we see at once that unusual magnetic disturbance is frequent about epochs of sun-spot maximum, and nearly or quite absent about epochs of sun-spot minimum, the general rise and fall in the number of days of great and active disturbance, concurrent with variation in sun-spot frequency, being sufficiently evident. In the approach towards sun-spot


12
6
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minimum there comes usually a time at which great disturbance ceases, whilst instances of active disturbance continue to occur; these ultimately also cease for a shorter or longer period at sun-spot minimum, after passing which disturbance is quickly renewed with rapidly increasing magnetic activity, in striking contrast to the more gradual dying down of activity as sun-spot mimimum is approached. Disturbance classed as great, including those seemingly irregular outbursts of the first magnitude when the magnets are so violently agitated, although more closely confined to the periods immediately preceding and immediately following epochs of sun-spot maximum, sometimes appears a considerable time afterwards. Thus there are instances of great disturbance between 1851 and 1854, following the sun-spot maximum of 1848, and in 1865 and 1866 following the sun-spot maximum of 1860; and there is a recent instance in 1898 following the sun-spot maximum of 1894, when in the years 1895 to 1897 no disturbance of the class great having occurred, there were two in 1898, on March 15 and September 9 respectively. Moderate disturbance is diminished in a remarkable degree at the sun-spot minimum of 1879, and in a lesser degree at that of 1856; at other of the epochs of sun-spot minimum there is little variation. In the class of minor disturbance there seems to be no definite variation concurrent with that of sun-spots. But the days of no disturbance show distinct increase in number at the sun-spot minimum of 1856, and a marked increase at the minimum of 1879. The cessation of great disturbance during the years 1875 to 1880, the small number of days of active disturbance, the diminished number of those of moderate disturbance, and the greatly increased number of those of no disturbance show the period about the sun-spot minimum of 1879 to have been one of extraordinary magnetic quiet, following as it did the unusually active sun-spot maximum of 1870.

The intervals at the several epochs of sun-spot minimum without magnetic disturbance of the class great were as follows:—

Period free from great disturbance.	Interval.	Epoch of sun-spot minimum.	Interval before minimum.	Interval after minimum.
1854·2 to 1857·3	3·1	1856·0	1·8	1·3
1866·1 to 1868·7	2·6	1867·2	1·1	1·5
1874·8 to 1881·1	6·3	1879·0	4·2	2·1
1886·2 to 1892·2	6·0	1890·2	4·0	2·0

The dead time at sun-spot minimum as regards great disturbance is thus variable in length, and the actual sun-spot minimum occurs when the interval is long towards the end of the dead time; but after the minimum is passed magnetic activity soon arises, more tardily, however, when the whole interval is long, probably consequent, as an old sun-spot cycle dies out, on the more or less speedy commencement in high solar latitudes of a

new cycle. In all, during the fifty years discussed, there were thus in the aggregate 18·0 years without any disturbance of degree here classed as great.

It may be interesting to add a list of the actual days on which, at Greenwich, disturbance of unusual character occurred. The list includes all days of the class of great disturbance, and a certain number of those of the class of active disturbance that approach the upper limit of this class. An asterisk affixed to the date indicates that the disturbance was of remarkable character. Occasionally disturbance would arise on the day next preceding, or would continue to the day next following, but more usually it was confined to the day mentioned. In cases, however, in which there was any accompanying prolonged disturbance, the interval over which it extended is added in brackets.

1848 January 16, February 21 (20 to 24), July 11, October 18,* November 17,* December 17.

1851 February 18, September 3, 6, 7* (3 to 7), September 29,* October 2 (September 29 to October 2), December 6, 29.

1852 February 14, 15, 17,* 18, 19* (14 to 21), June 11, November 11.*

1853 May 24, July 12.

1854 February 24, March 15, April 10.

1857 May 7, December 16.*

1858 April 9.*

1859 April 21, August 28,* September 1,* 2*, 3*(August 28 to September 5), October 12.*

1860 August 8, 9, 10, 12* (6 to 12), September 6.

1861 January 24, 25, 26 (22 to 27), December 19.

1862 July 5, August 4, October 3* (3 to 6), December 14.

1864 July 19.

1865 August 2, 3, 4 (2 to 5).

1866 February 20, 21, 25 (20 to 25).

1868 September 30.

1869 February 3, April 15,* May 13,* September 13.

1870 February 1, April 5, May 20,* August 20, September 24* (23 to 26), October 24,* 25.*

1871 February 12, April 1, 9, June 17,* August 24, November 2,* 10.

1872 February 4,* April 10, July 7,* 8,* August 3, 4, 8, 14, October 14,* 15, 16, 17* (14 to 18).

1873 January 7 (3 to 7), March 9.

1874 February 4, October 3 (3 to 5).

1880 August 12, 13.

1881 January 31*, September 12 (12 to 14).

1882 April 16,* 17,* 19* (16 to 20), June 24, August 4, October 2, November 16,* 17,* 19,* 20,* 21 (12 to 21).

1883 February 24, September 15, 16.

1884 July 3, November 2.

1885 March 15.

1886 January 9, March 29,* 30.

1892 February 13,* March 1, 6, 11, 12* (1 to 12), April 25, 26, May 18,* June 26, July 16,* August 12.*

1894 February 23, 25, 28 (20 to 28), March 20, July 20,* August 19,* September 14.

Some of the most remarkable disturbances were those of 1848 November 17, 1859 August 28 to September 5, 1872 February 4 and October 14 to 18, 1882 April 16 to 20 and November 12 to 21 (accompanied on November 17 by a very remarkable aurora), and 1892 February 13.

In cases of prolonged disturbance there is frequently a second outbreak after an intervening interval of moderate disturbance, and even of comparative quiet. Instances of this occurred in the disturbance of 1851 September 3 to 7, and that of September 29 to October 2 of the same year, also in those of 1852 February 14 to 21, 1859 August 28 to September 5, and 1882 April 16 to 20. In the disturbed period of 1892 March 1 to 12 there were three outbursts with intermediate moderate disturbance. On the other hand in the disturbance of 1860 August 6 to 12 considerable activity was maintained throughout, also in that of 1872 October 14 to 18, and in other cases. Remarkable disturbances occurred during a quiet period on 1870 October 24 and 25, accompanied on both nights by a fine aurora. Indeed, aurora was visible on many of the dates of the preceding list, but it formed no part of my intention to consider on the present occasion the relation of the aurora to magnetic disturbance.

We have seen that the magnetic activity prevalent about epochs of sun-spot maximum becomes greatly subdued or disappears about epochs of sun-spot minimum, indicating general relation between the two phenomena; and the appearance of a very large solar spot is usually accompanied by considerable magnetic disturbance, existing it may be for many days, as in 1882 November. But it is difficult to establish correspondence in details, or connect definite solar change with definite magnetic movement. The comparison is indeed one not easy to make, for although we possess continuous registers of magnetic variations no continuous record of solar change seems possible, and is indeed impossible for the face of the Sun that is turned away from the Earth. It is known that magnetic disturbance will break out with great suddenness simultaneously at widely different parts of the Earth's surface, indicating influence of cosmical character*; but the question is what action, solar or otherwise, determines the moment when simultaneously the whole Earth shall feel the initial magnetic impulse. Such sudden movements are not at all infrequent, and commonly presage magnetic disturbance or magnetic storm. I once began to make a list of the sudden initial movements that are to be found in the Greenwich records, and I believe it would be of interest to complete the list,

* *Proc. Royal Society*, vol. 52, p. 191.

as it appeared to me that there was some reason to suppose that the movements in question were more numerous when the Earth in its diurnal rotation stood in a given position in relation to the Sun. There is a further difficulty in regard to the comparison of solar and magnetic phenomena. Solar change and magnetic disturbance may either of them at times occur in marked degree without any apparently corresponding magnetic effect answering to the solar, or solar answering to the magnetic, or indeed any correspondence that can be distinctly traced. Thus the facts of observation, so far as known, are themselves in a degree perplexing.

Having dealt with the behaviour of magnetic disturbance from year to year, the same material may now be employed to consider more closely the variation in the frequency of disturbance through the course of the year; that is, develop from the aggregate of years 1848 to 1897 the character of the annual inequality as regards disturbance. Using the same convention as before for indicating different degrees of disturbance, there is given in Table II. the number of days of no disturbance, and of minor, moderate, active, and great disturbance, for half-monthly periods on the aggregate of years mentioned. In dividing 365 days into twenty-four parts, omitting as before February 29, there arise nineteen portions of fifteen days each and five portions of sixteen days each. The difference is one too large here to neglect. The numbers in each 16-day period have therefore been reduced by one-sixteenth part to make the whole comparative, and for these periods it is the corrected numbers that are given in Table II. It will be observed that this table contains no sun-spot values, the variation of solar-spot frequency having no annual period. It may, however, be desirable before proceeding further to show from the sun-spot numbers that this is the case. If there be an annual inequality, monthly values taken through a number of years should tend, as the aggregate of years employed is increased, to elimination of the eleven-year period, whilst at the same time bringing out an annual period, if any definite annual period exists. Having regard to the seasonal character of the variation to which the numbers of Table II. are subject, it will be sufficient to tabulate the sun-spot values for quarterly periods. Forming such quarterly values from Wolf's numbers, those derived directly from observation, combining together the fifty years 1848 to 1897, and taking the months of February, March, and April to represent Spring, and May, June, and July, to represent summer, and so on, we have :—

1848-1897 (50 years).	Spring.	Summer.	Autumn.	Winter.	Mean.
Mean sun spot number	50·5	49·3	48·3	46·7	48·7
					Numerical Sum.
Differences from Mean	+ 1·8	+ 0·6	− 0·4	− 2·0	4·8

As the separate quarterly sun-spot values, those of individual years, vary from 0 at sun spot minimum to 150 or more at sun-

spot maximum, these residuals are insignificant. But further, since Wolf has given monthly sun-spot values commencing with 1749, quarterly means can be formed in the same way as before for the whole period 1749 to 1897 : these are 47·4, 47·8, 47·5, and 47·0, respectively. Mean, 47·4. Differences from mean, 0·0, +0·4, +0·1, and −0·4. Numerical sum, 0·9, from a series of 149 years, as compared with 4·8 from a series of 50 years, an approach to equality of value, as the number of years employed is increased, that entirely negatives the supposition of the existence of an annual period.

TABLE II.

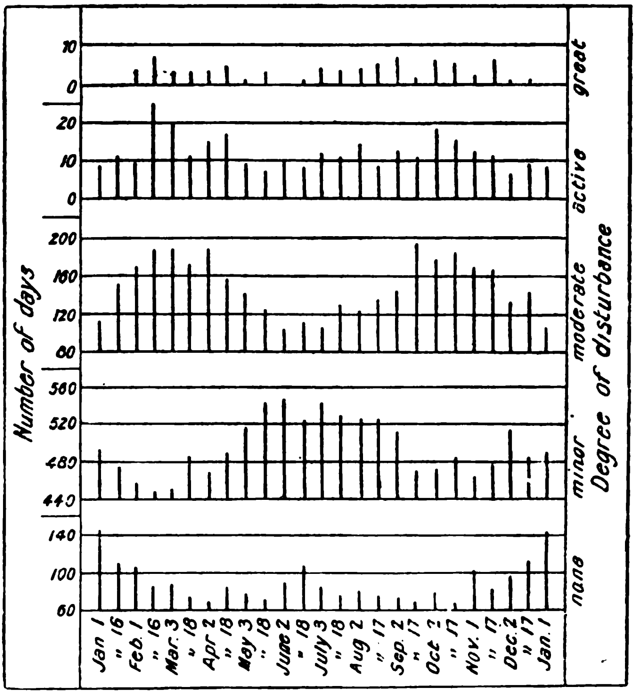
Number of Days of Magnetic Disturbance of Different Degrees of Intensity in Half-monthly Periods on the Aggregate of the Years 1848 to 1897, as deduced from the Records of the Royal Observatory, Greenwich.

Half Monthly Period.		Number of Days.	Middle Day of Period.	Degrees of Disturbance. None.	Minor.	Moderate.	Active.	Great.
Dec. 25	Jan. 8	15	Jan. 1	141	493	108	8	—
Jan. 9	23	15	16	108	477	154	11	—
24	Feb. 8	16	Feb. 1	106	460	171	9	4
Feb. 9	23	15	16	83	448	187	25	7
24	Mar. 10	15	Mar. 3	87	454	188	19	3
Mar. 11	25	15	18	78	483	174	11	3
26	Apr. 9	15	Apr. 2	70	472	189	15	4
Apr. 10	25	16	18	85	487	157	17	4
26	May 10	15	May 3	78	517	145	9	1
May 11	25	15	18	73	545	122	7	3
26	June 9	15	June 2	89	547	104	10	—
June 10	25	16	18	108	523	110	8	1
26	July 10	15	July 3	85	544	106	12	3
July 11	25	15	18	80	525	131	11	3
26	Aug. 9	15	Aug. 2	85	525	122	14	4
Aug. 10	24	15	17	77	524	136	8	5
25	Sept. 9	16	Sept. 2	74	514	143	13	6
Sept. 10	24	15	17	72	469	195	12	2
25	Oct. 9	15	Oct. 2	79	469	178	18	6
Oct. 10	24	15	17	66	481	182	16	5
25	Nov. 8	15	Nov. 1	101	465	169	13	2
Nov. 9	24	16	17	86	479	166	12	7
25	Dec. 9	15	Dec. 2	97	514	131	7	1
Dec. 10	24	15	17	111	483	146	9	1

From the numbers of Table II. the annexed diagram has been constructed. For the same reason as before the scale of days is made equal in length on the paper for the groups of no disturb-

ance and those of minor and moderate disturbance, but is quadrupled in length for the groups of active and great disturbance. We see in the diagram that great, active, and moderate disturbance is more frequent in spring and autumn than in summer and winter, the days of quiet magnetism, as represented by the classes of no disturbance and of minor disturbance, being correspondingly diminished at these seasons of the year. Conversely, when in summer and winter the frequency of great, active, and moderate disturbance declines, the days of quieter

Number of Days of Magnetic Disturbance of Different Degrees of Intensity in Half-Monthly Periods on the Aggregate of the years 1848 *to* 1897, *as deduced from the Records of the Royal Observatory, Greenwich.*



The day is the middle day of each half-monthly period.

magnetism become correspondingly increased—that is, magnetic activity at these seasons sinks to a lower level. It should be observed that the diagram represents the seasonal variation resulting from the combination of the whole fifty years 1848 to 1897, in which period years of different degrees of magnetic intensity occur. But, alike in years of lessened activity as well as in the more active years, the seasonal variation in the several classes of disturbance shows the same type of a diminished activity in summer and winter as is seen in the diagram.

The circumstance that magnetic activity is subject during the year to two maxima at or near the equinoxes, and two minima at or near the solstices, has been remarked at other places, M. Moureaux * having found a similar result from the discussion of the records of declination and horizontal force during the five years 1883 to 1887 at Parc Saint-Maur, as did Sabine † also previously from observations of declination at Toronto during the three years 1843 to 1845, the principal maximum in both cases falling at the autumnal equinox. In the Greenwich result there is no very marked difference between the spring and autumn maxima, and not very much difference between the summer and winter minima, although the winter seems to be the more quiet time. From observations made at Hobarton, during the same three years as at Toronto, Sabine found only one progression in the year, with a maximum in winter and a minimum in summer. Hobarton being in nearly the same latitude south as Toronto is north, this result would seem to require confirmation. It is, however, interesting that there should be such accordance as is above shown, considering that the Greenwich records have been treated in a somewhat different manner from that employed by Moureaux and Sabine. It is to be noted also that the Greenwich results depend on observations continued through a period of fifty years.

Magnetic disturbance is, as we see, most active around epochs of sun-spot maximum, and almost disappears about epochs of sun-spot minimum, both phenomena proceeding concurrently through a period of about eleven years. But by grouping together the same calendar month of different years it appears that magnetic activity is also greater in spring and autumn than in summer and winter, the seasonal difference in this respect being strongly marked. Thus, whilst sun-spot frequency continuously progresses from maximum to minimum, and from minimum again to maximum, there is superposed on the corresponding progression of magnetic disturbance an annual variation, having maxima at the equinoxes and minima at the solstices, to which, as has been shown in this paper, there is no counterpart in the progression of sun-spot frequency. It would thus appear that the progression in the case of magnetic disturbance becomes modified by the influence of terrestrial action. At the equinoxes, when magnetic activity becomes increased, the Earth in its diurnal revolution presents successively its whole surface to the Sun, but at the solstices, when magnetic activity becomes diminished, the region about one or other terrestrial pole is continually in shadow. Here then is a succession of phases in the Earth's annual movement relatively to the Sun apparently harmonising in time with the seasonal variations of magnetic activity. It might be interesting to be able to compare these results with others

* *Annales du Bureau Central Météorologique de France*, 1887, *Mémoires*, p. B. 35.

† *Phil. Trans. for* 1851, p. 123.

obtained from the records of some station in the southern hemisphere, but no lengthened series of results for any southern station appears to be available. The circumstance that the diurnal magnetic range in our latitude is greatest in summer and least in winter, and in corresponding southern latitudes is, in like manner, greatest and least in the southern summer and winter respectively, indicates that similar astronomical circumstances are accompanied by similar magnetic conditions. Now in the frequency of magnetic disturbance there is, in our latitude, a double progression with maxima at the equinoxes and minima at the solstices. If here also similar astronomical circumstances are accompanied by similar magnetic conditions, we should expect to find in corresponding southern positions also maxima of disturbance frequency at the equinoxes and minima at the solstices, a point on which it would be interesting to have further information.

The two papers contained, one in the *Philosophical Transactions for the year* 1880, and the other in vol. 63 of the *Proceedings of the Royal Society* (1898), and the present paper, together complete the work that I originally contemplated doing in regard to sympathetic relation between terrestrial magnetism and sun-spots. It may therefore be useful to add a brief summary of the results arrived at :—

1. Magnetic registers include mainly the effects of two phenomena, the solar diurnal variation and the irregular magnetic disturbance. On days of quiet magnetism the solar diurnal variation is alone present ; but on most days magnetic disturbance, superposed on the diurnal movement, exists to a lesser or greater extent.

2. The diurnal range of declination and horizontal force at the Royal Observatory, Greenwich—in forming which days of magnetic disturbance are included, excepting only those of extreme character—is found to vary, both in period and magnitude, in close accordance with the variation of sun-spot frequency throughout the series of years employed.

3. It was afterwards found that this variation is of the same character in every respect when days of quiet magnetism are alone employed ; the variation is consequently a feature of the undisturbed diurnal range.

4. A distinct relation also exists between magnetic disturbance, considered apart from diurnal variation, and sun-spot frequency, more or less marked, much more marked in some sun-spot periods than in others, there having been great magnetic activity at the sun-spot maximum of 1870, and unusual magnetic quiet at the sun-spot minima of 1856 and 1879—in a remarkable degree at the latter epoch.

5. That is to say, when the phenomena of diurnal variation and magnetic disturbance—which exist in combination

in the magnetic registers—are separated, it is found that each one in itself varies independently with the variation of sun-spot frequency.

6. Further, there is an annual inequality in the frequency of magnetic disturbance, having maxima at the equinoxes and minima at the solstices, to which there is no counterpart in the variation of sun-spot frequency.

Mean Areas and Heliographic Latitudes of Sun-spots in the year 1898, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal*).

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lix. p. 4, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich; at Dehra Dûn, India; and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1898; and Table II. gives the same particulars for the entire year 1898 and the nine preceding years, for the sake of comparison. The areas are given in two forms: first, projected areas—that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1898 the mean daily area of whole spots, the mean heliographic latitude of the spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1897 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888, on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853, November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854, January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected Whole Spots.	Corrected Faculæ.
	d							
592	1897 Dec. 28·64	27	103	558	986	74	422	1136
593	1898 Jan. 24·98	28	142	799	969	92	528	1190
594	Feb. 21·32	27	211	1127	1045	147	781	1231
595	Mar. 20·64	27	36	196	755	27	150	856
596	Apr. 16·92	27	47	278	728	39	229	913
597	May 14·16	28	25	159	677	18	115	832
598	June 10·36	27	13	80	562	8	51	666
599	July 7·56	27	38	219	474	28	161	530
600	Aug. 3·77	26	121	657	546	79	437	670
601	Aug. 31·01	27	192	1194	857	134	863	984
602	Sept. 27·28	28	118	732	894	82	553	1007
603	Oct. 24·57	27	142	826	1007	88	516	1077
604	Nov. 20·87	26	62	336	682	48	247	740

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected for Foreshortening. Whole Spots.	Corrected for Foreshortening. Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410
1897	364	122	695	977	88	514	1149
1898	363	93	532	767	64	375	891

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	d			°		°	°	°
592	1897 Dec. 28·64	27	281	8·61	142	9·60	+ 2·50	8·94
593	1898 Jan. 24·98	28	120	4·72	408	7·70	− 4·86	7·00
594	Feb. 21·32	27	125	10·50	656	11·45	− 7·92	11·30
595	Mar. 20·64	27	0	...	150	11·61	−11·61	11·61
596	Apr. 16·92	27	9	12·68	220	8·59	− 7·76	8·75
597	May 14·16	28	9	9·06	106	12·22	−10·49	11·96
598	June 10·36	27	19	15·13	33	10·06	− 0·85	11·92
599	July 7·56	27	76	10·29	85	12·41	− 1·69	11·41
600	Aug. 3·77	26	194	10·18	243	11·92	− 2·12	11·14
601	Aug. 31·01	27	68	8·25	795	11·69	−10·13	11·42
602	Sept. 27·28	28	164	13·53	389	10·88	− 3·65	11·67
603	Oct. 24·57	27	432	10·32	84	10·84	+ 6·88	10·41
604	Nov. 20·87	26	6	6·19	242	10·92	−10·53	10·81

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
1889	360	5·0	7°·26	73·0	11°·90	−10°·68	11°·61
1890	361	53·1	22·20	46·3	21·75	+ 1·73	21·99
1891	363	401	20·49	169	19·91	+ 8·52	20·31
1892	362	607	15·09	607	21·69	− 3·29	18·39
1893	360	517	14·91	941	14·26	− 3·93	14·49
1894	364	543	12·31	739	15·56	− 3·75	14·18
1895	364	565	14·26	409	12·54	+ 3·01	13·54
1896	364	203	13·60	340	14·77	− 4·15	14·33
1897	364	196	8·32	318	7·73	− 1·62	7·96
1898	363	110	9·82	266	10·77	− 4·75	10·49

The principal features of the record for 1898 are :—

1. The decline in area of umbræ and whole spots, which seemed to have suffered a check in 1897, had resumed its regular course. The decrease in mean daily spotted area amounted to 27 per cent. for 1898 as compared with 1897, and to 31 per cent. as compared with 1896.

2. The decrease in the area of the umbræ has been in almost exactly the same proportion as for the whole spots—27 per cent. as compared with 1897, 29 per cent. as compared with 1896.

3. The decrease in the area of the faculæ has also been considerable—22 per cent. as compared with 1897, 37 per cent. as compared with 1896.

4. The decline in the whole spots has been chiefly in the northern hemisphere, the decrease as compared with 1897 being 44 per cent. for the northern hemisphere, but only 16 for the southern.

5. The predominance in spot activity of the southern hemisphere, noted in 1897, has become more striking in 1898.

6. The year has been marked by three chief outbreaks of spots. The first began on March 6, with the simultaneous appearance, at equal distances from the equator, of two fine groups in the same longitude, but one north and the other south of the equator. The greatest group of the year made its first appearance as one or two very small faint spots on August 11, and was quite insignificant up to the time of its disappearance at the W. limb after August 16. It had become a magnificent group by its return on September 3, and was still rapidly increasing. It attained its greatest area, 2,235 millionths of the visible hemisphere, on September 10, and then began to decline. It was still a fine group at its third appearance on September 30, but was rapidly diminishing, and at its fourth return on October 28 only a few small spots remained. The third chief group of the year was first seen on October 22, but appeared only for a single passage.

7. The chief characteristic of the year 1898 has been the return to a higher mean distance of the spots from the equator—viz., to $10^{\circ}\cdot 5$ instead of 8° in 1897. As this latitude accords well with that usually occupied by the spots at this stage of the decline towards minimum, 1897 stands out as having been quite abnormal, both as to its slight decline in area and its great decline in latitude.

8. The number of days without spots has increased, being 48 for 1898, as against 32 in 1897 and 8 in 1896. The number of days without faculæ was 11.

9. The year 1898 closely resembles the year 1886 as to mean daily spotted area, mean distance of spots from the equator, and number of days without spots. If the decline follows the course of the last cycle the next minimum should fall towards the end of 1901.

Observations of the Leonid Meteors of 1899 *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

Twenty meteors were observed in the morning of November 16, two of these during a partial break between 4.30 and 4.40 A.M., and the other eighteen during a clear period between 5.30 and 6.15 A.M. Thirteen of these meteors conformed to the *Leo* radiant. A continuous watch by three observers was kept from 11 P.M. to 6 A.M. on November 14–15 and November 15–16, but dense fog on the former night and cloud on the latter prevented any observations except during the above-mentioned periods.

Arrangements were also made to photograph meteors on the two nights, but owing to the weather no results were obtained.

A watch was also kept for the Bielid meteors on the nights of November 23 to 27, but the sky was generally covered with cloud, and no meteors were seen.

The following table shows the number of meteors seen at the Leonid epoch in each of the years 1887 to 1899 at Greenwich:—

Year.	Date of Observation.	Length of effective Watch.	Total Number of Meteors.	Number of Leonids.	Remarks.	No. of Observers.
1887	Nov. 15	A few minutes	2	1	Cloudy	1
1888	...	...	...	...	Quite cloudy	...
1889	Nov. 12–13	2^h	7	0	Cloudy generally	1
1890	...	...	...	...	Quite cloudy	...
1891	Nov. 13–14	2^h	0	0	Generally clear; bright moonlight	1
1892	Nov. 12–13	$1\frac{1}{2}^h$	0	0	Thin cloud	1
	„ 14–15	Brief	1	0	Cloudy generally	1
1893	Nov. 12–13	3^h	21	4	...	1
	„ 13–14	$1\frac{1}{2}^h$	9	1	Watch suspended on account of cloud	2
1894	...	...	...	...	Cloudy throughout	...
1895	Nov. 12–13	4^h	30	5	...	2
	„ 13–14	2^h	19	7	Observations stopped by cloud	2
1896	Nov. 12–13	2^h	8	2	...	3
	„ 15	$1\frac{1}{2}^h$	10	5	...	1
1897	Nov. 14	2^h	14	8	...	3
1898	Nov. 15–16	Brief	1	1	Cloudy	1
1899	Nov. 16	1^h	20	13	Cloudy	3+

Royal Observatory, Greenwich:
1899 *December* 8.

Observations of the Leonids of 1899, *made at the University Observatory, Oxford.* By H. H. Turner, Savilian Professor.

Preparations were made to observe the expected shower, but came to nothing. Mr. Bellamy had about seven cameras ready and four in reserve, to photograph the trails in different parts of the sky, and exposed some plates on November 14, but with no result. Messrs. H. Mullis, B. Gray, and E. Gray kept a regular watch on the sky in turns of half an hour each from $10^{h}\cdot30$ to $18^{h}\cdot0$ on the nights of November 14 and 15; and about thirty members of the University passed these nights at the Observatory, some of them watching, others sleeping on the floor of the Lecture-room, so that they might be quickly roused and carry the news to different colleges if there was a sensational shower. But nothing out of the common was observed. The following notes of details may be recorded:—

November 13. Cloudy at midnight. From $15^{h}\ 45^{m}$ to $16^{h}\ 15^{m}$, G.M.T., 5 Leonids and 2 other meteors seen by Professor Turner.

Nov. 14. Cloudy from $10\frac{1}{2}^{h}$ to 14^{h}. Cleared between 14^{h} and 15^{h}, and became a splendid night. The Moon and bright stars seen close to horizon. Moon set at 17^{h}.

The following meteors were counted by Messrs. H. Mullis, B. Gray, and E. Gray:—

G.M.T. Nov. 14. h h	Observer.	Number Leonids.	Of Others.
15 to $15\frac{1}{2}$	H.M.	2	—
$15\frac{1}{2}$ „ 16	B.G.	4	1
16 „ $16\frac{1}{2}$	E.G.	3	2
$16\frac{1}{2}$ „ 17	H.M.	8	—
17 to $17\frac{1}{2}$	B.G.	9	—
$17\frac{1}{2}$ „ 18	E.G.	18	—
18 „ $18\frac{1}{2}$	H.M.	3	—

These observers were watching the radiant and its neighbourhood. A few other meteors not included in above were observed by Mr. Bellamy, who was in charge of the cameras in the dome, Mr. H. Hilton, Fellow of Magdalen, and Councillor G. C. Druce, who were with him, as follows:—

Sid. Time (Greenwich). h	m	s	
6	48	40	3rd mag. midway ζ and μ Leonis towards 20 Leonis path 12° long, rapid.
8	11	10	2° north of μ Leonis and R.A. 10^{h}.
8	12	25	East to west through Orion, long trail.
8	16	0	Near Procyon to Sirius, long trail.
8	25	10	In Leo.
8	56	10	Large meteor though Ursæ Min.
9	16	35	Near the zenith, the brightest seen during the night; caused a sudden glare of light over the landscape and left a trail for some minutes.

About 6 others were seen in *Orion*, and quite 25 near *Leo*, but times or paths were not noted, most of them until 18^{h} would be included in the above counts.

November 15. Cloudy all night; rifts in clouds 17^{h} to 18^{h}, but no meteors seen through them.

November 16. 11^{h} to 18^{h}. Brilliantly clear at times, but no meteors seen by Mr. Bellamy, who kept an intermittent watch.

Observations of the Leonids of 1899 *November* 14 *and* 15, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by A. A. Rambaut, M.A., D.Sc., Radcliffe Observer.*)

At the Radcliffe Observatory we made careful preparations for observing the *Leonid* shower this year.

Our attention was chiefly devoted to an attempt to photograph some of the meteor trails and to an enumeration of the meteors seen. The staff of the Observatory being limited in number, it seemed to me best to confine observations to these two objects; and as the results obtained by Professor Pickering and one or two others in recent years seem to show that even a few photographic trails will give a better determination of the actual position of the radiant point than a much larger number charted down by eye and hand, I decided, after some hesitation, not to attempt any observations by the latter method.

For the photographic observations a camera carrying a Ross portrait lens of $4\frac{1}{2}$-inch aperture and about 18 inches focal length was attached to the declination axis of the Barclay 10-inch equatorial, the latter being used as a guiding telescope during the exposure of the plates. The camera was adapted for whole plates, which covered a field of about 30° by 20° on the sky.

From some experiments made previously with this apparatus by sweeping the telescope, we had concluded that if a meteor as bright as a first-magnitude star appeared in the neighbourhood of the radiant point during the exposure of a plate, we should be likely to obtain a photograph of its trail. The plates used were Edwards' Isochromatic Snap Shot Plates.

Unfortunately, however, although Mr. McClellan and I kept exposing plates from shortly after 15^{h} on the 14th until dawn put a stop to our observations, no trails were obtained.

Mr. Wickham and Mr. Robinson undertook the count of the meteors. They were stationed on the roof of the eastern wing of the Observatory tower. A cable had been temporarily laid to the chronograph, by which Mr. Wickham was enabled to register the time of appearance of each meteor to a fraction of a second. Mr. Robinson was also furnished with a pocket enumerator registering up to 12,000. Unfortunately, the richness of the display fell so far short of anticipation that the value of these

arrangements for registering the numbers was not put to the test.

Our watch commenced at 10^h on November 14. At 11.30, however, the sky became overcast, and remained so until about $14^h\ 30^m$, when the clouds lifted towards the east.

The number of *Leonids* observed in each quarter of an hour is given below. The actual times of appearance of thirty-one meteors observed by Mr. Wickham have been read to the nearest second from the chronograph, but it does not appear necessary to print these times.

G.M.T. h m	No. of Meteors Observed.	G.M.T. h m	No. of Meteors Observed.
14 45 – 15 0	5	16 30 – 16 45	3
15 0 – 15 15	2	16 45 – 17 0	5
15 15 – 15 30	2	17 0 – 17 15	4
15 30 – 15 45	3	17 15 – 17 30	8
15 45 – 16 0	4	17 30 – 17 45	9
16 0 – 16 15	0	17 45 – 18 0	5
16 15 – 16 30	3	18 0 – 18 15	6
		18 15 – 18 30	1

In all only sixty *Leonids* were recorded, of which thirty-seven were noted by one observer and thirty-five by the other. In addition several sporadic meteors were also seen.

The increasing number of meteors between $16^h\ 30^m$ and 18^h may possibly be due to the darkening of the sky as the Moon approached the horizon. It set at about 17^h G.M.T.

At $17^h\ 40^m\ 1^s$ a very brilliant meteor was seen by all four observers. It passed from *Leo* through a point midway between *Polaris* and *Capella*. It exhibited a bright train which nearly disappeared after two or three seconds. Then a portion of the train reappeared, brightened, and quickly changed form. After a little while the train bent in the middle and seemed to consist of two straight portions inclined at an obtuse angle to each other. By $17^h\ 41^m$ it had become indefinite and distorted into an irregular sinuous figure. At $17^h\ 43^m$ it seemed to hang from the star 22 (Hev.) *Camelopardali*, and had drifted a little towards *Polaris*. At this time its axis was situated at right angles to its former position. It eventually broke into two portions and faded away at $17^h\ 46^m\ 4^s$.

On the following night (November 15) a watch was again instituted, but up till midnight a fine drizzle prevailed, and the sky remained obstinately overcast until after 17^h. At about $17^h\ 30^m$ the clouds began to part, and breaks occurred large enough to reveal whole constellations at a time, but no meteors were seen. These breaks were sufficiently open and numerous to

enable a definite opinion to be formed that the radiant then was very inactive. The sky again became overcast at $17^h\ 46^m$, and remained so until after sunrise.

Observations of the Leonids of 1899, *made at Durham Observatory.*

(*Communicated by Professor R. A. Sampson.*)

Preparations were made for a count of the expected shower upon a plan adapted from that of Professor E. C. Pickering's Harvard Circular. Maps and directions were given to between thirty and forty correspondents, here and at various places in Yorkshire, Durham, and Northumberland. The sky was divided into six segments, meeting at the radiant and passing through (1) *Regulus*—ϵ *Hydræ*, (2) ϵ *Hydræ*—*Pleiades*, (3) *Pleiades*—*Pole*, (4) *Pole*—ζ *Ursæ Majoris*, (5) ζ *Ursæ Majoris*—β *Leonis*, (6) β *Leonis*—*Regulus*. Each observer was to count the number of meteors appearing per minute in his own segment. It was hoped that thus the count might be pushed nearer the maximum, and perhaps some result of interest might appear as to whether the shower began on one side and died away on another. In the actual event the display was so meagre that the directions given were unsuitable, and little interest attaches to the observations except as an item of the average.

At the Observatory watch was kept on November 11, 12, 13, $16^h\ 30^m$—18^h; and November 14, 15, 11^h—18^h. On the 12th, 13th, and 14th it was densely clouded. Mr. F. C. H. Carpenter and myself watched on the 11th, and on the 14th and 15th we were joined by six of my students. We saw the following meteors, besides others which were not from the radiant in the Sickle. The paths of some of these were charted.

No.	Time.		Segment of Sky.	Note.
		h m		
1	Nov. 11	17 31	5	b k g.
2	15	13 27	6	

Between $13^h\ 27^m$ and $15^h\ 40^m$, five or six meteors seen, of which exact record was not taken.

No.	Time.		Segment of Sky.	Note.
		h m		
3	Nov. 15	16 3	2	
4		16 14	2	k or.
5		16 26	6	k y.
6		16 33	5	
7		16 35	3	
8		16 38	4	k bl.
9		16 41	6	k g.
10		16 42	6	k bl.

No.		Time. h m	Segment of Sky.	Note.
11	Nov. 15	16 48	2	vb k (5 seconds), curved path.
12		16 51	4	k or.
13		17 6	2	k bl.
14		17 8	5	y.
15		17 10	3	y.
16		17 24	5	k bl.
17		17 25	2	bl.
18		17 27	2	
19		17 41	6	b k bl.
20		17 45	6	k y.
21		17 46	6	b or.
22		17 49	2	k bl.
23		17 50	3	b k g.
24		17 52	4	k or.
25		18 4	3	or.
26		18 8	5	bl.
27		18 17		

b = bright, k = streak, g = green, bl = blue, or = orange, y = yellow, v = very.

The numbers that appeared in successive quarters of an hour from $15^h\ 45^m$ to $18^h\ 15^m$ were respectively, 0, 2, 1, 5, 2, 3, 3, 2, 4, 2, or at the rate of 1 in $6\frac{1}{4}$ minutes. If for the sake of illustration we analyse these according to the segments in which they were seen, we get

Segment.	1	2	3	4	5	6	7	8	9	Totals.
1	...	...	...	...	...	...	...	...	...	0
2	...	...	...	1	1	2	...	1	...	5
3	2	...	1	...	1	...	...	1	1	6
4	...	...	1	1	...	...	...	1	...	3
5	...	...	1	...	1	1	...	...	1	4
6	...	1	2	...	...	...	2	1	...	6
Totals	2	1	5	2	3	3	2	4	2	24

It seems odd that none was seen in the first segment; apart from this the directions seem indiscriminate. But the numbers are altogether too small to carry any weight.

Durham: 1899 *November* 27.

Results of Observations of the Leonid Meteors of 1899 *as seen from the Royal Observatory, Edinburgh.* By George Clark, M.A.

(*Communicated by the Astronomer Royal for Scotland.*)

The sky in the neighbourhood of *Leo* was carefully watched during the whole of the night of Tuesday, November 14, and Wednesday, November 15, from 10.30 P.M. till 6.30 A.M. on each occasion. On both nights the sky was perfectly cloudless, but the fact that the gibbous Moon was riding high in the heavens made it difficult to observe the fainter meteors, and proved a serious drawback to photographic work.

The first *Leonid* on Tuesday was seen at $11^h\ 45^m$, and from then on till 16^h they occurred at long intervals, sometimes even half an hour elapsing without a single meteor being observed. As each appeared its apparent path was marked as accurately as possible on previously prepared maps. After 16^h it became evident that the shower was increasing, and the meteors gradually occurred more frequently till 17^h, when for a short time they appeared at average intervals of perhaps one minute.

Throughout the whole night the great majority of the paths radiated from the vicinity of the Sickle towards the southern half of a circle described round the radiant, very few meteors being observed to travel in a northerly direction. There was no difficulty whatever in discriminating between the *Leonids* and other meteors of a more sporadic nature which from time to time flashed across the sky. The radiant character of the former was very evident, and is distinctly brought out by the paths as drawn on the maps. Moreover, the *Leonids* shot forth with great swiftness, and were of an intense bluish-white colour, bearing indeed a marked resemblance to certain kinds of rockets. They had the same sort of bright bulb at the head, and left similar trails, some of which, even in the bright moonlight, persisted for several seconds. Some of these trails were very long, indicating that the meteors had passed "broad on" to the observer; while others were much foreshortened, owing to perspective. It was noticeable that these very short paths were almost all entirely within the bounds of the Sickle. The meteors seen between 17^h and $17^h\ 30^m$ seemed to be the most brilliant of the display; but as the Moon set at $17^h\ 19^m$ this was doubtless largely due to the consequent greater darkness of the sky. It did not occur to any of us that what we saw at this time could possibly represent the main stream of meteors, and hopes were confidently entertained that the grandest part of the display was still to come.

On Wednesday night, however, there was a considerable amount of haze; and at 14^h a damp, heavy fog came on, which lasted for about an hour. Owing to these circumstances it is more than likely that faint meteors entirely escaped observation;

indeed, during the whole watch of seven hours only two meteors of any description were seen, neither of them being a *Leonid.*

Arrangements were made by Mr. Heath for photographing the meteors by mounting two cameras—one of them for plates 18″ by 16″—on the 24-inch reflecting telescope. Between 17^h and 18^h on Tuesday, while the display was at its best, two plates were exposed; but unfortunately the attempt was not attended with any success.

Two charts were used on which to draw the apparent paths of the meteors observed. The first contains thirty-two meteors, and was in use on Tuesday night from 11^h till $16^h\ 30^m$; while the second contains forty-two meteors observed on the same night between $16^h\ 30^m$ and $18^h\ 45^m$. For the directions of several paths on each map I am indebted to Dr. Halm.

The method adopted in determining the apparent radiant point and the results obtained are briefly as follow:—

In the first place the arrows on each map were taken in pairs, such that the components of each pair were as nearly as possible at right angles to one another, no single arrow being made use of more than once. In this way twelve pairs were obtained on the first map and fourteen on the second. The exact position of the intersection of each pair was then determined, with the results exhibited in Table I.

TABLE I.

Map I.		Map II.	
R.A.	Decl.	R.A.	Decl.
h	°	h	°
10·10	+24·0	9·92	+22·7
10·06	22·0	9·88	22·5
9·88	23·9	10·02	21·2
10·04	23·2	9·98	22·9
9·93	23·6	9·97	21·9
10·06	23·4	9·97	21·9
9·98	22·8	10·02	23·4
9·86	21·5	10·08	23·1
9·90	23·4	9·97	23·2
10·01	22·8	9·98	24·1
9·90	22·0	10·00	23·2
10·05	24·0	9·82	22·5
		9·96	22·0
		9·98	22·2

The mean of the results in Map I. is—

$$\text{R.A. } 9^h\ 58^m{\cdot}8 \pm 1^m{\cdot}4\ ;\ \text{Decl. } +23^\circ\ 3' \pm 15'{\cdot}3$$

and in Map II.—

$$\text{R.A. } 9^h\ 57^m{\cdot}6 \pm 1^m{\cdot}0\ ;\ \text{Decl. } +22^\circ\ 37'{\cdot}2 \pm 12'{\cdot}4\ ;$$

while the mean of the results of both maps taken together is

$$\text{R.A. } 9^{h}\ 58^{m}{\cdot}2 \pm 0^{m}{\cdot}8\ ;\ \text{Decl. } +22^{\circ}\ 48'{\cdot}0 \pm 9'{\cdot}5.$$

To compute the amount of the zenith attraction, and the *true* position of the radiant point, it was necessary first to determine the zenith distance (Z) of the *apparent* radiant. This was computed (1) for the hour angle of the apparent radiant corresponding to the mean of the times (viz. $15^{h}\ 0^{m}$) at which the observations on the first map were made, and (2) for the similar hour angle at the mean of the times (viz. $17^{h}\ 37^{m}$) recorded on the second map. The amount of the zenith attraction was then obtained from Schiaparelli's formula

$$\tan \tfrac{1}{2}\,\phi = \frac{w-\omega}{w+\omega}\ \tan \tfrac{1}{2}\,Z,$$

where ϕ=zenith attraction ; w=accelerated velocity of meteors due to Earth's attraction ; ω=orbital velocity of meteors ; and Z=apparent zenith distance of radiant.

Finally, to determine the corrections to the R.A. and Decl. of the apparent radiant, we have

$$d\alpha = \phi \sin \eta \sec \delta\ ;\ d\delta = -\phi \cos \eta,$$

η being the parallactic angle.

The results thus deduced are arranged in order in the following table (II.) :—

TABLE II.

Map.	Z.	ϕ	$d\alpha$.	$d\delta$.	Corrected Position of Apparent Radiant. R.A.	Corrected Position of Apparent Radiant. Decl.	Weight.
	° ′	′	m	′	h m	° ′	
I.	49 25·8	20·2	+0·8	−16·6	9 59·0	+22 31·4	1
II.	34 8·5	13·5	+0·2	−13·2	9 58·4	+22 34·8	1·16

By combining the R.A.'s and declinations given in the last two columns according to their weights, the mean position of the *true* radiant point was found to be

R.A. $9^{h}\ 58^{m}{\cdot}6$; Decl. $+22^{\circ}\ 33'{\cdot}2$ (equinox of 1900·0).

Assuming this position for 1899 November, 14·73 G.M.T., the elements of the orbit have been computed for the period 33·25 years. But, as remarked by Dr. Rambaut in his paper reprinted from the *Proceedings of the Royal Society*, vol. lxv., there appears to be reason for believing that the most probable value of the period of revolution is at present about 33·49 years. The elements have therefore also been computed for this period, and the two sets of results are given in the first two columns of Table III. subjoined. For the sake of reference Dr. Rambaut's results for 1898 are given in column 3. Column 4 contains the elements for 1866 as established by the late Professor Adams, and column 5 the elements of the orbit of Comet I., 1866 (Temple's)

as computed by Dr. von Oppolzer. In each of these last two cases the elements have been brought up to the epoch 1900·0.

TABLE III.

		1 Edinburgh, 1899.	2	3 Rambaut, 1898.	4 Adams, 1866.	5 Comet I., 1866.
Period	P	33·25 yrs.	33·49 yrs.	33·49 yrs.	33·25 yrs.	33·17582
Mean Distance	a	10·34	10·39	10·39	10·34	10·3247
Angle of Eccentricity	ϕ	64°45′·0	64°48′·7	64°50′·0	64°47′·0	64°52′·8
Inclination	i	16°31′·3	16°31′·2	16°3′·0	16°45′·87	17°17′·95
Longitude of ☊	☊	52°39′·7	52°39′·7	53°2′·0	51°54′·97	51°53′·75
Longitude of Perihelion	π	56° 1′·7	56° 4′·2	58°40′·0	58°45′·17	42°52′·5
Perihelion Dist.	q	0·98789	0·98794	...	0·9885	0·97652
Time of Perihelion Passage	T	Nov. 12^{d}·257	Nov. 12^{d}·251	...	...	Jan. 11·13388

Royal Observatory, Blackford Hill, Edinburgh:
1899 *December* 7.

Erratum in Monthly Notices, vol. lx. page 18 (last line).

For 9^{m} to $\cdot 49^{m}\cdot 2$, *read* $9^{m}\cdot 4$ to $9^{m}\cdot 2$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. JANUARY 12, 1900. No. 3

Professor G. H. DARWIN, M.A., LL.D., PRESIDENT, in the Chair.

Professor R. N. Apte, M.A., LL.B., Rajaram College, Kolhapur, India ;
Maurice Harvey Clarke, Lieut. R.N.R., F.R.G.S, Coleswood, Harpenden, Herts ;
Rev. P. W. Fairclough, Kaiapoi, New Zealand ;
Umes Chandra Ghosh, M.A., Muir Central College, Allahabad, India ;
Richard Kilvington Hattersley, 4 Church Terrace, Blackheath, S.E. ; and
Howard Payn, F.R.G.S., 21 Hyde Park Place, W.,

were balloted for and duly elected Fellows of the Society.

Sixty-six presents were announced as having been received since the last meeting, including amongst others :—

L. Ambronn, Handbuch der Astronomischen Instrumentenkunde, presented by the author ; Nice, Observatoire, Annales, Tome i., presented by M. Bischoffsheim ; Paris, Observatoire, Carte Photographique du Ciel, Zone 24 (19 charts), presented by the Observatory ; Isaac Roberts, Photographs of stars, star clusters and nebulæ, vol. ii., presented by the author ; S. Newcomb, Tables of *Uranus* and *Neptune*, presented by the Office of the American Ephemeris ; Photograph of the nebula H V. 14 *Cygni*, presented by Mr. Wilson ; Photograph of the nebula in *Orion*, presented by the Astronomer Royal.

The Determination of Selenographic Positions and the Measurement of Lunar Photographs. By S. A. Saunder, M.A..

The object of this paper is to call attention to the great uncertainty that attaches to our knowledge of the positions of lunar formations, and to suggest means by which these positions may be determined more accurately than has yet been accomplished.

§1. *Errors in Existing Measures.*

Schmidt, in the introduction to his *Charte der Gebirge des Mondes*, gives a list of 157 formations whose positions have been determined as "points of the first order," almost entirely by Lohrmann (76), Mädler (89), and Neison (33). If to these we add the positions of Biot, found by Mädler; Horrocks, Halley, and Hipparchus L, by Neison; with Triesnecker B, by Pritchard, we have, so far as I know, all the points whose positions have been found by methods making any pretension to accuracy; and of these very little reliance can be placed on those which depend on not more than two or three measures. The uncertainty attaching to a single measure was estimated by Mädler* to be about 8″ or 9″ (geocentric), which would correspond to half a degree of selenographic longitude or latitude near the centre of the disc, and to a still greater amount as the limb is approached. The probable error derived from the measures themselves, *after rejecting the unfavourable points*, is stated by Neison† to be 7″·2. Rather less than half the whole number given by Schmidt depend upon 10 or more measures, whether by the same or by different observers.

Eleven points were measured five times at least by both Lohrmann and Mädler. The average difference in selenographic latitude is 17′, and in longitude 10′, corresponding respectively to 4″·4 and 2″·3 geocentric. It may also be noted that in nine cases Lohrmann's position is further from the equator than Mädler's, and the mean distance of his positions from the equator is greater than Mädler's by 12′ of selenographic latitude, or 3″·4 as seen from the Earth. The differences in longitude so far as these points are concerned do not appear to be systematic.

§ 2. *Possible Cause of Systematic Error.*

The method adopted by Lohrmann, Mädler, and Neison was that suggested by Encke, in which the position of a point is determined by measuring its distance from either the N. or S.

* *Der Mond*, § 39.
† *Quarterly Journal of Science*, April 1875.

limb, and also from the E. or W., according to the state of illumination. Lohrmann found the diameter of the Moon by measuring the line joining the cusps ; Mädler by computation from Encke's ephemeris.

A personal equation is known to exist in observations of the Moon's limb, and no indication of the error due to this cause is given by the probable error of a series of measures obtained from those measures themselves, whilst in comparing one observer with another we find only the difference in the extent to which the two are affected by this or any other systematic error, so that the real errors may be much larger than would be inferred from this probable error, combined with the result of such a comparison.

I think we may see one direction in which systematic error is likely to occur.

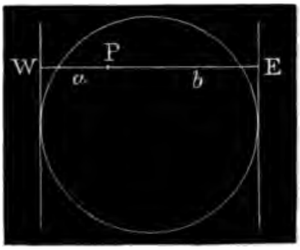


Fig. 1.

Let P be a point whose position is to be found.

Let PW$=a$, PE$=b$, be its distances from the west and east limbs respectively.

Let $2r$ be the Moon's diameter.

All these quantities will in consequence of irradiation be measured too great. Suppose there is a definite increment or personal equation, due to this cause, and call it x. The measured diameter is increased by $2x$, the radius by x, so that, if we measure from the west limb, instead of determining $\frac{a}{r}$ we really measure $\frac{a+x}{r+x}$, and as $a<r$, it follows that $\frac{a+x}{r+x}>\frac{a}{r}$, and the resulting position is too near the central meridian.

Mädler and Neison seldom measured a point from both limbs, Lohrmann usually did so ; but if P were measured from the east limb we should measure $\frac{b+x}{r+x}$ instead of $\frac{b}{r}$, and as $b>r$, it follows that $\frac{b+x}{r+x}<\frac{b}{r}$,

and again the point is brought too near the central meridian.

N 2

Mädler's computed radius was also affected by irradiation, but the assumption that the increments of the numerator and denominator have a tendency to equality becomes less probable in his case.

Measures from the north or south limb would be similarly affected, and we might expect measures made in this way to give latitudes and longitudes numerically too small. I shall offer some evidence that this has been the case, and suggest that this is a real, though I believe not the only, cause of systematic error.

§ 3. *Proposed Substitution of Measures from a known Point.*

The great difficulty of measuring from the limb has always been recognised; it has been suggested that transits of a well-defined formation, as Mösting A, should be observed in preference to transits of the limb, and tables are given in the *Berliner Jahrbuch* to facilitate their reduction. Neison proposed that measures for selenographic positions should similarly be taken from a well-determined point; but so far as I am aware neither he nor anyone else has ever published an account of measures made in this way.

§ 4. *Correction of the Measures for Libration.*

I expect that the real reason why so few selenographers have given attention to this branch of the work is to be found in the very forbidding character of the reductions necessitated by the Moon's librations. This certainly would have prevented my ever taking it up had it not been that I mentioned the difficulty to Professor Turner, who suggested the following elegant method of shortening the computation by the use of rectangular coordinates:—

Let ξ, η, ζ be the "standard" coordinates of any point referred to rectangular axes through the Moon's centre, the axis of η being the Moon's polar axis, that of ζ the radius through the intersection of the equator with the first meridian.

Let x, y, z be the "instantaneous" coordinates of the same point, the axis of y being the projection of the Moon's central meridian on the plane normal to the line of sight; that of z the line of sight through the centre of the disc; so that the "instantaneous" coincide with the "standard" coordinates under mean libration.

The ordinary formulæ for the transformation of coordinates give

$$\left.\begin{aligned} x&=a_1\xi+b_1\eta+c_1\zeta \\ y&=a_2\xi+b_2\eta+c_2\zeta \\ z&=a_3\xi+b_3\eta+c_3\zeta \end{aligned}\right\} \quad (1)$$

and for the reverse transformation

$$\left.\begin{aligned}\xi&=a_1x+a_2y+a_3z\\ \eta&=b_1x+b_2y+b_3z\\ \zeta&=c_1x+c_2y+c_3z\end{aligned}\right\}\quad(2)$$

If l', b' be the Moon's librations in longitude and latitude respectively it is easily shown that

$$\left.\begin{array}{lll}a_1=\cos l', & a_2=-\sin l'\sin b', & a_3=\sin l'\cos b'\\ b_1=0, & b_2=\ \ \cos b', & b_3=\sin b'\\ c_1=-\sin l', & c_2=-\cos l'\sin b', & c_3=\cos l'\cos b'\end{array}\right\}\quad(3)$$

Now take the Moon's radius as the unit of length.
Let d=the distance of the Moon's centre from the observer,
s'=the Moon's angular semidiameter;

then $$d=\frac{1}{\sin s'},$$

and the equations to the line of sight which passes through
(a) the position of the observer, 0, 0, d,
(b) the point observed, x, y, z,

are $$\frac{X}{x}=\frac{Y}{y}=\frac{Z-d}{z-d}.$$

This meets the plane of projection, Z=0, at the point whose coordinates are

$$\frac{xd}{d-z},\ \frac{yd}{d-z},\ 0$$

or $$\frac{x}{1-z\sin s'},\ \frac{y}{1-\sin s'},\ 0.$$

Let Q be the measured distance between two points (x, y, z), (x', y' z'), expressed as a fraction of the Moon's radius.

P, the position angle of the direction of Q from (x, y, z) to (x', y', z').

C, the position angle of the axis of y.

$C-\frac{\pi}{2}$ is the position angle of the axis of x;

and we have

$$\frac{x'}{1-z'\sin s'}-\frac{x}{1-z\sin s'}=Q\cos\left(P-C+\frac{\pi}{2}\right)=-Q\sin(P-C).$$

$$\frac{y'}{1-z'\sin s'}-\frac{y}{1-z\sin s'}=Q\sin\left(P-C+\frac{\pi}{2}\right)=Q\cos(P-C).$$

These equations may be written

$$\left.\begin{aligned} x_1'-x&=-\mathrm{Q}\sin(\mathrm{P}-\mathrm{C})(1-z\sin s') \\ y_1'-y&=\quad\mathrm{Q}\cos(\mathrm{P}-\mathrm{C})(1-z\sin s') \end{aligned}\right\} \quad (4)$$

where $x'=x_1'(1-z'\sin s')(1-z\sin s')^{-1}$

$$=x_1'\{1-(z'-z)\sin s'-z(z'-z)\sin^2 s'+\ldots\}$$

$$\left.\begin{aligned} &=x_1'\{1-(z'-z)\sin s'(1+z\sin s')\}\text{ approximately} \\ &\text{Similarly} \\ &y'=y_1'\{1-(z'-z)\sin s'(1+z\sin s')\}\quad ,, \end{aligned}\right\} \quad (5)$$

Since $\sin s'<\cdot 005$, this approximation is always close enough; and, unless $z'-z$ is large, the term in $\sin^2 s'$ may also be rejected.

If (x, y, z) be the point whose position is known, equations (4) give us the values of x_1', y_1'.

From these may be found $z_1'=\sqrt{1-x_1'^2-y_1'^2}$.

And if we use this, instead of z', in equations (5), we can find x', y'.

The error introduced in x' by using this approximate value of z is sensibly $x_1'(z_1'-z')\sin s'$.

From equations (5) we see that

$$x_1'-x'=x_1'(z'-z)\sin s' \text{ approximately};$$

$$y_1'-y'=y_1'(z_1-z)\sin s' \quad ,, \quad ;$$

whence $$z_1'-z'=\frac{x_1'^2+y_1'^2}{z_1'}(z'-z)\sin s';$$

and the error in x' becomes $x_1'\dfrac{x_1'^2+y_1'^2}{z_1'}(z'-z)\sin^2 s'$ (6)

Unless we are working close to the limb, this will be insensible. If necessary its value may be computed, again using z_1' instead of z'; but I have never had to do this.

The computation may therefore be arranged as follows:—

(*a*) Find x, y, z, the "instantaneous" coordinates of the known point by (1).

(*b*) Find x_1', y_1' by (4).

(*c*) Find $z_1'=\sqrt{1-x_1'^2-y_1'^2}$.

(*d*) Find x', y' by (5), using z_1' instead of z'.

(*e*) Find $z'=\sqrt{1-x'^2-y'^2}$.

(*f*) Find ξ', η', ζ', the "standard" coordinates of the unknown point, by (2).

If the selenographic longitude and latitude are required they can be found from $\sin(\text{lat.})=\eta'$, $\cos(\text{lat.})\sin(\text{long.})=\xi'$.

Note that when z' has been computed by (*e*) we can at once form the value of $z'-z$, and determine whether the residual (6) is sensible.

Quite apart from the shortening of the work, Professor Turner's method has the very important advantage that, beyond finding the sine and cosine of P—C, no reference to any trigonometrical tables is required. No attempt has been made to adapt the work to logarithmic computation. As it stands, the operations are just those in which the "Brunsviga" excels, and by the use of this machine the computation becomes purely mechanical.

§ 5. *Computation of the Librations.*

It remains to explain the method adopted in computing the librations. As was pointed out by Neison, these need not be so exactly determined as was necessary in Encke's method, but an approximate correction for parallax is required.

The following tables are used :—

(1) The values of N, log cot n and log sin n, as proposed by Gauss, where

$$\tan N = \cot.\phi \cos \tau$$
$$\cot n = \sin N \tan \tau$$

τ between the hour angle and ϕ the latitude.

These are tabulated for every minute with argument τ, and are used in correcting for refraction, and also in determining the Moon's apparent altitude from

$$\sin (\text{alt.}) = \sin n \sin (N + \delta').$$

(2) A table constructed on the same principle for converting right ascension and declination into latitude and longitude. A very complete table of this form, with corrections for variations in obliquity of the ecliptic is given in Hansen's *Tables de la Lune*, but the simpler form, given in the *American Ephemeris* from 1855 to 1864 for mean obliquity, is all that is necessary.

(3) Tables giving (1) $\frac{a - a'}{\pi}$ the parallax in right ascension as a fraction of the horizontal parallax ;

(2) $\frac{\delta - \delta'}{\pi}$ the parallax in declination as a fraction of the horizontal parallax

computed from the equations

$$\frac{a - a'}{\pi} = \rho \cos \phi' \sin t \sec \delta$$
$$\tan \gamma = \tan \phi' \sec t$$
$$\frac{\delta - \delta'}{\pi} = \rho \sin \phi' \sin (\gamma - \delta) \operatorname{cosec} \gamma,$$

(see Chauvenet, vol. i. art. 101) and tabulated with the double arguments, a and δ.

These formulæ are not rigorous, but the parallax found from them is quite near enough.

(4) A table giving the augmentation of the Moon's semi-diameter with the apparent altitude as argument.

It is also useful to have tables for converting minutes and seconds of arc, as well as time, into the decimals of a degree.

The geocentric librations, l, b, are taken from the very useful ephemeris prepared by Mr. Crommelin, for which the thanks of all selenographers are due to him.

The parallax in α and δ is taken from tables (3), the necessary data being given in the *Nautical Almanac*. The apparent α' and δ' are converted in longitude and latitude λ', β' by tables (2).

The geocentric longitude and latitude λ, β may be similarly computed and compared with the values given in the *Nautical Almanac* for verification.

The corrected librations l', b' are then found from

$$l'=l-(\lambda-\lambda') \qquad b'=b+(\beta-\beta')$$

which, though not rigorous, are sufficiently close.

The Moon's apparent altitude is computed by table (1), and another verification is found as follows: The total parallax is added to the apparent altitude, giving the geocentric altitude. From this the co-latitude is subtracted, and, treating the remainder as a declination, the corresponding value of $\frac{\delta-\delta'}{\pi}$, when $a=0$, is taken from table (3). This, multiplied by π, the horizontal parallax, should again give, very approximately, the total parallax.

The value of s, given in the *Nautical Almanac*, is corrected for altitude by table (4); the result corresponds to the "bright radius," and must be reduced by $1''\cdot5$ in order that Q may be expressed as a fraction of the "dark" or occultation radius, as determined by Dr. L. Struve from the lunar eclipses of 1884 and 1888. I do not think there can be any question that this radius should be employed in preference to the "bright" radius affected by irradiation.

Finally the value of C is computed by each of the formulæ given in the preface to the *Nautical Almanac*, the agreement serving as a further verification.

§ 6. *Method and Results of Observation.*

The reductions are still long, and it is therefore desirable to make the observations with care, the mean of several measures made consecutively taking no longer to reduce than a single measure. My usual method in the most recent work has been to take three settings for position angle, turn the position circle through 180° and take three more; then to take three readings

for distance with the webs open, *i.e.* each on the same side of the field as its own screw head ; five with the webs crossed, or each nearer to the opposite screw head ; and two more with the webs open ; finally to take six more settings for position angle as before. In this way the mean time for the position angle becomes nearly the same as that for the distance. If this condition is not fulfilled a correction to the position angle may be required, as when the Moon's right ascension is near 6 hours or 18 hours the value of C changes by about 15′ an hour.

The whole set takes from half to three quarters of an hour. This may seem long, but measuring on the Moon has difficulties of its own in addition to those encountered in estimating the centres of the formations. Owing to the varying motion in right ascension it is seldom that the clock is exactly adjusted, nor is it worth while to attempt more than an approximate adjustment, for there is always the motion in declination outstanding. This makes it far from easy to fix the webs on two distant points, and to verify the setting. The greater the distance the greater the difficulty. The change in libration during the interval is not sufficient to sensibly affect the measures, and a few points accurately measured are of more value than a greater number less carefully obtained.

Most of the work I have done by this method has been directed to fixing the positions of the smaller formations in a restricted region, but it may be also applied to determining the more important points.

The only point on the Moon whose position is known with real accuracy is Mösting A, as determined by Professor Franz from Schlüter's observations with the Königsberg heliometer. These were made under Bessel's direction for the determination of the Moon's physical libration. Mösting A was the point observed, and its resulting position, as given in an appendix to vol. xxxviii. of the *Königsberg Observations*, is

$$\lambda = -5^\circ\ 10'\ 19''\cdot0 \pm 7''\cdot9 \qquad \beta = -3^\circ\ 11'\ 24''\cdot0 \pm 5''\cdot5.$$

The following measures, made and reduced as described above, give a fair idea of the accuracy with which positions can be obtained by this method. They are selected as being useful for comparison with results obtained from photographic measures in the second part of this paper, but at present I call attention only to the mutual agreement of different measures of the same point.

Ptolemaus, A. (*Centre.*)

1898 Sept. 30	$\xi = -\cdot0141$	$\eta = -\cdot1484$
Dec. 22	$-\cdot0139$	$-\cdot1476$
23	$-\cdot0138$	$-\cdot1476$
1899 Jan. 23	$-\cdot0136$	$-\cdot1475$
Feb. 19	$-\cdot0141$	$-\cdot1475$
Mean	$-\cdot0139$	$-\cdot1477$

Herschel. (*Summit of cone.*)

1898 Dec.	22	$\xi = -\cdot0370$	$\eta = -\cdot0988$
	23	$-\cdot0370$	$-\cdot0993$
1899 Feb	19	$-\cdot0371$	$-\cdot0989$
	Mean	$-\cdot0370$	$-\cdot0990$

Dollond. (*Centre.*)

1899 Nov.	13	$\xi = +\cdot2460$	$\eta = -\cdot1817$
	16	$+\cdot2458$	$-\cdot1813$
	18	$+\cdot2455$	$-\cdot1818$
Dec.	11	$+\cdot2459$	$-\cdot1820$
	Mean	$+\cdot2458$	$-\cdot1817$

Manilius. (*Summit of cone.*)

1899 Nov.	13	$\xi = +\cdot1544$	$\eta = +\cdot2497$
Dec.	11	$+\cdot1531$	$+\cdot2493$
	13	$+\cdot1537$	$+\cdot2497$
	Mean	$+\cdot1537$	$+\cdot2496$

Hesiodus B. (*Centre.*)

1899 Dec.	14*	$\xi = -\cdot2670$	$\eta = -\cdot4553$
	15	$-\cdot2673$	$-\cdot4553$
	Mean	$-\cdot2672$	$-\cdot4553$

Euclides. (*Centre.*)

1899 Dec.	13	$\xi = -\cdot4886$	$\eta = -\cdot1279$
	15	$-\cdot4887$	$-\cdot1283$
	Mean	$-\cdot4887$	-1281

These positions all carry with them any error in that of Mösting A, but this, I believe, is a very small quantity.

When it is remembered that the last place here given has a geocentric value of something less than $0''\cdot1$, and that the probable error of either coordinate from one night's work deduced from these results is $\cdot00017$, or about $0''\cdot16$ (geocentric), whilst no divergence from the mean exceeds $0''\cdot7$, it will be seen that the agreement is very different from that attained by Encke's method (see §1).

* An incomplete set, stopped by clouds.

§ 7. *Measurement of Photographs.*

The results I was obtaining by this method offered such great promise that last Easter I again consulted Professor Turner as to the possibility of applying it to the measurement of lunar photographs. He entered most cordially into the idea, and in addition to giving many valuable suggestions as to methods, he promised to lend me a micrometer, and wrote to M. Loewy asking for photographs on my behalf.

M. Loewy, with great generosity, at once sent four of his incomparable negatives, with terminators at about $+14^\circ$ M., -11° M., $+18{\cdot}5$ E., $-7{\cdot}5$ E., so that all the principal formations are well shown, and Mr. Bellamy, of the Oxford University Observatory, very kindly made positive copies on glass of the second and third of these with *réseaux*. This proved a more difficult operation than I had anticipated. When the copies were dense enough to bring out the detail the *réseau* was lost in the shadows and on the darker parts of the surface. Eventually successful copies were obtained, but only after much careful and patient work, for which, as well as for the kindness and heartiness with which it was undertaken, I owe him my warmest acknowledgments.

I was not able to commence work upon the plates until August, and in the meantime Mr. Bellamy had measured thirty-six points of the first order on a copy of the third plate. I subsequently found approximate values for the radius and coordinates of the centre, and then proceeded to determine constants for the plate on a method suggested by Professor Turner, analogous to that devised by him for the reduction of the astrographic chart plates.

§ 8. *Correction for Finite Distance.*

The first thing to be done is from the measured, conically projected, values of the *réseau* coordinates $x+\delta x$, $y+\delta y$, to deduce the orthogonally projected coordinates x, y of the same point. In other words we have to correct for the finite distance of the Moon.

The axes of x, y being in the same plane as in § 4, we have as there shown

$$x=(x+\delta x)(1-z \sin s') \qquad y=(y+\delta y)(1-z \sin s').$$

or $$\delta x=(x+\delta x)\, z \sin s' \qquad dy=(y+\delta y)\, z \sin s'$$

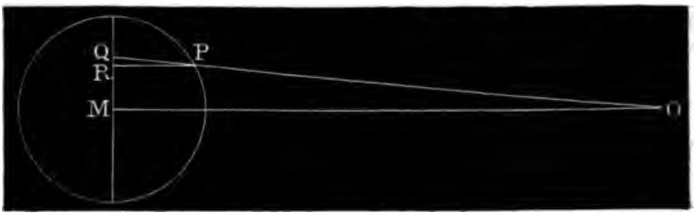


Fig. 2.

If O be the position of the observer,
P the point observed,
M the centre of the Moon,
Q, R the conical and orthogonal projections of P respectively,
Let the radius of the Moon be the unit of length :

$$MR=r \quad MQ=r+\delta r \quad PR=z=\sqrt{1-r^2}$$

and let the corresponding value of z for the point at which the ordinate through Q meets the sphere be $z+\delta z$, so that $z+\delta z=\sqrt{1-(r+\delta r)^2}$.

Then, since δr, δz are small,

$$r\delta r=-z\delta z.$$

From the values just found for δx, δy we have

$$\delta r=(r+\delta r)z \sin s'$$

$$\therefore \delta z=-\frac{r}{z}\delta r$$

$$=-r(r+\delta r)\sin s'$$

$$=-(r+\delta r)^2 \sin s' \text{ approximately.}$$

Hence the required corrections may be written

$$\delta x=(x+\delta x)\{(z+\delta z)\sin s'-\delta z \sin s'\}$$
$$=(x+\delta x)\{(z+\delta z)\sin s'+(r+\delta r)^2\sin^2 s'\}.$$

Similarly

$$\delta y=(y+\delta y)\{(z+\delta z)\sin s'+(r+\delta r)^2\sin^2 s'\}.$$

These may be computed from the measured values $x+\delta x$, $y+\delta y$, the terms in $\sin^2 s'$ being always less than ·000025.

§ 9. *Failure of the First Attempt to Determine Constants for the Plate.*

The further corrections to be applied to x, y are those for errors of centre and scale, for refraction and for optical distortion. These with the transformation necessary to deduce the values of the "standard" coordinates ξ, η, ζ are all linear, and therefore we have

$$x=A\xi+B\eta+C\zeta+D$$
$$y=E\xi+F\eta+G\zeta+H,$$

where A, B . . . H are constants for the plate ; and if these are known, the equations are sufficient to determine ξ, η, ζ, which are connected by the relation $\xi^2+\eta^2+\zeta^2=1$.

In order to determine the constants, the accepted coordinates of the points measured by Mr. Bellamy were substituted with the corresponding values of x, y, giving a group of thirty-six equations for A, B, C, D, and thirty-six for E, F, G, H, the two groups differing only in the absolute terms x, y.

When the solution was effected by least squares, the probable errors of C, D were ·0043, ·0041 respectively, and the mean of the eight probable errors was ·0022. The probable error in the longitude of the centre therefore corresponded to more than 5″ (geocentric), whilst the positions obtained for Mösting A and one or two of the best known points were between 2″ and 3″ (geocentric) too far east. The residuals from the conditional equations in x (*i.e.* the value of $A\xi+B\eta+C\zeta-x$) ranged from $-·0128=-12''·0$ geocentric to $+·0074=+6''·9$ geocentric, the numerical mean being $·0029=2''·7$, the corresponding mean for the y group being $·0020=1''·9$, showing, as is apparent all through the work, that the latitudes have been better determined than the longitudes. But these residuals were too large to be accounted for by errors in the photographic measures, and the constants were so badly determined that the only conclusion was that the accepted places were not good enough for what was required of them.

Though disappointing in the immediate result, this was in other ways encouraging. It showed that a revision of the places was necessary, and that the photographic measures were adequate to effect it, if a method could be devised to make them yield the information they contained.

§ 10. *General Principle of the Solution.*

Eventually the following was adopted.

The time and place at which each photograph was taken being known, all the information required as to scale, position of centre, and plane of projection could be obtained partly by computation, partly by measures on the photograph, but the orientation could not be so obtained.

It was noted that the second and third of the photographs sent by M. Loewy, taken a little after first and a little before third quarter respectively, were under very different librations. When these librations were computed, the absolute position of the centre of the disc in each photograph became known; and if these two positions could be combined, we should have a direction from which the orientations might be obtained. But it was doubtful whether the distance between the centres would prove sufficient to fix this direction with the required accuracy.

A pretty close physical interpretation of the process adopted may be given as follows :—

The two plane pictures were by no means superposable, and a difference in configuration on the common zone was easily

seen over quite a small area. If, then, these two pictures could be put into a stereoscope—as De la Rue did—they would give a solid picture of the Moon on which the relative positions of the formations could be observed; but there is only one way in which they could be put into the stereoscope, so that combination by the eyes might be possible. Again, the knowledge of the librations gave us the position of the plane of projection referred to the equator and first meridian, and so it would be possible to construct for each picture a corresponding projection of a set of meridians and parallels of latitude which might be fitted on to the picture if only we knew how to orientate it. If these two projections were put into the stereoscope, without the Moon pictures, there would again be only one way of doing it which would enable the two to be combined by the eyes. If these projections were made on glass, so that the photographs of the Moon could be seen through them, and all four pictures were put into the stereoscope together, we should, when all four were adjusted, see the meridians and parallels on the Moon itself, and could read off the latitude and longitude of any desired point. And, further, as we should have thus found how to place the meridians and parallels on each picture, we could take them out of the stereoscope and obtain a separate reading of the position of any point on each photograph, or determine the position of a point shown on one plate only.

§11. *First Approximation to the Constants of the Plates.*

The analytical process was as follows. The optical librations were carefully computed with Franz's value of the inclination of the Moon's equator, a rigorous formula being used for the parallax. To these were added the physical librations taken from the *Berliner Jahrbuch*, the signs there given being reversed for this purpose, as noted by Mr. Crommelin in his last Ephemeris. The results were :—

Reference Number.	Date.	Librations.		Appro longitud Termin
II.	1899, Feb. 18^{d} 6^{h} 30^{m} 14^{s}, Paris sid. t.	$l' = +5^\circ\ 1'\cdot7$.	$b = -1^\circ\ 57'\cdot2$	-11°
III.	1895, Sept. 9^{d} 1^{h} 38^{m} 2^{s}, „ „	$-6^\circ 34'\cdot4$,	$-5^\circ\ 53'\cdot6$	$+18^\circ\cdot$

from which it follows that the selenocentric distance between the centres of the two discs is $12^\circ\ 13'$.

The zenith distances and the parallactic angles at the centres of the discs were computed at the same time.

Professor Turner has kindly allowed me to see the unpublished MS. of Professor Pritchard's measures of photographs made in his investigation of the Moon's physical libration. From these I find that he obtained the following positions :—

Ptolemaus A, $\xi = -\cdot0144$, $\eta = -\cdot1483$ from 60 photographs.
Triesnecker B, $\xi = +\cdot0066$, $\eta = +\cdot0202$ „ 52 „

The probable error of Professor Pritchard's determination of Ptolemaus A was a little greater than that of mine as given in § 6, but the two positions differ only by about half a second (geocentric) in each coordinate, and the means $\xi = -·0142$, $\eta = -·1480$, may be taken as very nearly accurate.

These, with Professor Franz's position of Mösting A, $\xi = -·0900$, $\eta = -·0556$ gave three points whose positions seemed trustworthy, and which were employed as stated below.

If x, y be the *réseau* coordinates of any point corrected for finite distance and refraction, referred to the centre, and expressed as fractions of the Moon's radius; and z is the third coordinate of the same point formed from the equation $x^2+y^2+z^2=1$; ξ, η, ζ the "standard" coordinates of the same point; θ the angle through which the *réseau* axis of y must be turned to bring it into coincidence with the projection of the Moon's central meridian, the positive direction of rotation being the same as for position angles, the ordinary formulæ for transformation of coordinates give

$$\xi = (\cos l' \cos\theta - \sin l' \sin b' \sin\theta)x - (\cos l' \sin\theta + \sin l' \sin b' \cos\theta)\,y + \cos b' \sin l'\,z$$

$$\eta = \cos b' \sin\theta\,x + \cos b' \cos\theta\,y + \sin b'\,z$$

which may be written

$$\left.\begin{aligned} \xi &= \mathrm{A}x + \mathrm{B}y + \mathrm{C}z \\ \eta &= \mathrm{D}x + \mathrm{E}y + \mathrm{F}z \end{aligned}\right\} \quad (7)$$

And the problem is to determine the value of θ.

In Plate II. 39 points on the limb were measured, and in Plate III. 36 points.

A selection from these gave approximate values of the coordinates of the centre and of the Moon's radius, in *réseau* intervals.

The *réseau* coordinates of the three known points were then measured, corrected for everything except refraction, and substituted in (7).

From these equations were then deduced an approximate value of θ for each plate.

In expressing the coordinates as fractions of the radius, I assumed that the radius measured on the photograph was the "bright" radius, given in the *Nautical Almanac*, which accords very closely with Professor Pritchard's determination of the Moon's photographic diameter (*Memoirs R.A.S.*, vol. xlvii.)

This was reduced by $1''·5$ as in § 5.

§ 12. *Coordinates of the Zenith, and Correction for Refraction.*

The coordinates of the zenith were then found from the equations

$$\mathrm{X} = \tan\zeta' \sin(\mathrm{C}+\theta-q')$$
$$\mathrm{Y} = \tan\zeta' \cos(\mathrm{C}+\theta-q')$$

where ζ' is the computed apparent zenith distance,

C the position angle of the Moon's central meridian, computed as in § 5,

q' the parallactic angle at the centre of the disc.

The measured coordinates could now be corrected for refraction, these corrections being

$$57''\{(1+X^2)x+XYy\} \text{ to } x \text{ and } 57''\{(1+Y^2)y+XYx\} \text{ to } y.$$

[*Monthly Notices*, vol. liv. p. 19.]

the numerical values of which were

for Plate II., $\cdot 0003x$ to x and $\cdot 0003y$ to y,
for Plate III., $\cdot 0003x$ to x and $\cdot 0004y$ to y,

the second term being insensible in each case.

§ 13. *Determination of Centre and Radius.*

From the whole group of corrected limb measures an attempt was then made to find the final coordinates of the centre and the radius of the disc. Unfortunately the Oxford University Observatory *réseau* was not large enough to cover the whole limb, and from this it resulted that the abscissa and radius were poorly determined. The limb measures were therefore combined with those of the three known points, and the final values deduced from the whole.

The values of the two radii showed that on the scale adopted a side of a *réseau* square on Plate II. corresponded to $57''\cdot 57$; on Plate III. to $57''\cdot 62$. Assuming the side to be exactly 5mm. the corresponding focal lengths of the object glass would be 17·915m. and 17·899m. Unfortunately this focal length has never been accurately determined.

It is interesting to note that the figures give a smaller mean radius in Plate II., where we measure from the W. limb, than in Plate III., where we measure from the E. limb, the difference being $0''\cdot 8$. Professor Pritchard found from his measures of the photographic diameter that the W. limb did give a semidiameter smaller by $0''\cdot 2$ than the E. limb, so that part of the difference may be due to this cause. As one photograph was taken in February, the other in September, it is probable that there would be some difference in the focal length.

§ 14. *Determination of the Orientation.*

Values had now been obtained for all the constants of the plate except θ, the value of which, deduced from the three known points, was liable to sensible error in consequence of their nearness to the centre.

To determine this, sixty-two points were measured on both plates on the zone common to the two, and all the corrections applied.

Twenty points were rejected on account of difficulty in reading the *réseau*, or unsuitable illumination on one or other of the plates. This left the forty-two points shown in Table I., the measures of which were considered satisfactory.

If a small error has been made in θ, it will be found by differentiating equations (7) that the true values of ξ, η are given by

$$\xi = Ax + By + Cz + (Bx - Ay)\delta\theta$$
$$\eta = Dx + Ey + Fz + (Dx - Ey)\delta\theta$$

If therefore we use the suffixes 2, 3, to denote the plate to which the corresponding quantity belongs, I had to find values of $\delta\theta_2$, $\delta\theta_3$, which would make $\xi_2 = \xi_3$, $\eta_2 = \eta_3$.

This gave forty-two equations of the type

$$(Ax + By + Cz)_2 - (Ax + By + Cz)_3 + (Bx - Ay)_2\,\delta\theta_2 - (Bx - Ay)_3\,\delta\theta_3 = 0$$

and forty-two of the type

$$(Dx + Ey + Fz)_2 - (Dx + Ey + Fz)_3 + (Dx - Ey)_2\,\delta\theta_2 - (Dx - Ey)_3\,\delta\theta_3 = 0.$$

The normal equations derived from the ξ group were

$$\left.\begin{array}{r} 9205\delta\theta_2 - 8871\delta\theta_3 + 41{\cdot}70 = 0 \\ -8871\delta\theta_2 + 8695\delta\theta_3 - 40{\cdot}35 = 0 \end{array}\right\} \quad (8)$$

Those from the η group

$$\left.\begin{array}{r} 273\delta\theta_2 + 172\delta\theta_3 - {\cdot}20 = 0 \\ 172\delta\theta_2 + 714\delta\theta_3 - 2{\cdot}46 = 0 \end{array}\right\} \quad (9)$$

which combine to

$$\left.\begin{array}{r} 9478\delta\theta_2 - 8699\delta\theta_3 + 41{\cdot}50 = 0 \\ -8699\delta\theta_2 + 9409\delta\theta_3 - 42{\cdot}81 = 0 \end{array}\right\} \quad (10)$$

the solution being

$$\left.\begin{array}{l} \delta\theta_2 = -{\cdot}00134 \pm {\cdot}00027 \\ \delta\theta_3 = +{\cdot}00331 \pm {\cdot}00027 \end{array}\right\} \text{ in circular measure.}$$

The resulting positions are given in Table I. for each plate, with columns showing the differences, and the results obtained by previous observers for comparison.

TABLE I.

List of Forty-two Points measured on Plates II. and III. from which the Values of $\delta\theta_2$, $\delta\theta_3$ were deduced.

	ξ_2	ξ_3	$\xi_2-\xi_3$	η_2	η_3	$\eta_2-\eta_3$	Other Observers. ξ	η	Authority.
Lilius	+·0621	+·0610	+·0011	−·8131	−·8141	+·0010			
„ sm. crater near* ...	+·0619	+·0621	− 2	−·7961	−·7966	+ 5			
Licetus *d*	+·0566	+·0554	+ 12	−·7724	−·7729	+ 5			
„ H	+·0383	+·0380	+ 3	−·7182	−·7184	+ 2			
Huggins †	−·0286	−·0301	+ 15	−·6495	−·6498	+ 3			
Stöfler K	+·0567	+·0567	0	−·6353	−·6355	+ 2			
Orontius *d*	−·0829	−·0831	+ 2	−·6346	−·6345	− 1			
Miller	+·0096	+·0098	− 2	−·6339	−·6339	0			
Walter *a* ‡	+·0095	+·0088	+ 7	−·5936	−·5938	+ 2			
„ sm. crater § ...	−·0023	−·0027	+ 4	−·5547	−·5546	− 1			
Lexell	−·0580	−·0588	+ 8	−·5815	−·5818	+ 3			
Aliacensis	+·0758	+·0760	− 2	−·5062	−·5064	+ 2			
Werner central mount. ...	+·0539	+·0544	− 5	−·4689	−·4689	0	+·0502 +·0458	−·4551 −·4658	Lohrmann Mädler
„ N.E. mount. ‖ ...	+·0456	+·0454	+ 2	−·4655	−·4663	+ 8			
Purbach A	−·0295	−·0296	+ 1	−·4406	−·4408	+ 2			

* The most westerly of three confluent craters of which the easternmost is *b*.
† The interior crater in contact with the N.E. wall.
‡ The small isolated crater S. of Walter.
§ The isolated crater on the S.E. part of the floor.
‖ The mountain on the N.E. part of the floor.

	ξ_2	ξ_3	$\xi_2-\xi_3$	η_2	η_3	$\eta_2-\eta_3$	Other Observers. ξ	η	Authority.
Faye	+·0617	+·0620	− 3	−·3651	−·3648	− 3			
Donati	+·0838	+·0837	+ 1	−·3523	−·3526	+ 3			
Arzachael *c*	+·0199	+·0204	− 5	−·3176	−·3179	+ 3			
Airy	+·0955	+·0948	+ 7	−·3103	−·3101	− 2			
„ sm. crater *	+·0744	+·0747	− 3	−·3026	−·3025	− 1			
Argelander...	+·0975	+·0974	+ 1	−·2843	−·2848	+ 5			
Alphonsus	−·0465	−·0457	− 8	−·2311	−·2316	+ 5	−·0551	−·2248	Mädler
Albategnius A	+·0444	+·0449	− 5	−·2073	−·2065	− 8			
Ptolemaus A	−·0139	−·0141	+ 2	−·1479	−·1479	0	−·0144 −·0108	−·1483 −·1492	Pritchard Neison
Hipparchus G	+·1290	+·1292	− 2	−·0871	−·0870	− 1			
„ *n*	+·0874	+·0870	+ 4	−·0843	−·0841	− 2			
„ H	+·0528	+·0526	+ 2	−·0385	−·0381	− 4			
Mösting A	−·0906	−·0905	− 1	−·0557	−·0555	− 2	−·0900	−·0556	Franz
Triesnecker B	+·0068	+·0065	+ 3	+·0205	+·0206	− 1	+·0066	+·0202	Pritchard
Murchison A	+·0198	+·0198	0	+·0697	+·0700	− 3	+·0174	+·0709	Neison
Pallas	−·0279	−·0288	+ 9	+·0948	+·0954	− 6			
Bode...	−·0422	−·0420	− 2	+·1173	+·1177	− 4	−·0436 −·0460	+·1155 +·1155	Lohrmann Neison
Bode A	−·0200	−·0201	+ 1	+·1568	+·1571	− 3	−·0229	+·1547	Neison

* To the E. of Airy, almost in contact with the wall.

	ξ_1	ξ_2	$\xi_1-\xi_2$	η_1	η_2	$\eta_1-\eta_2$	Other Observers. ξ	η	Authority.
Conon	+·0325	+·0324	+ 1	+·3699	+·3697	+ 2	+·0317	+·3669	Lohrmann
Aratus	+·0728	+·0726	+ 2	+·4006	+·4007	− 1			
Archimedes A	−·0982	−·0984	+ 2	+·4700	+·4703	− 3	−·1106	+·4656	Neison
,, c	−·0220	−·0225	+ 5	+·5241	+·5241	0			
,, b	−·0266	−·0278	+ 12	+·5705	+·5701	+ 4			
Piton	−·0102	−·0108	+ 6	+·6540	+·6528	+ 12			
Cassini b	+·0523	+·0517	+ 6	+·6428	+·6427	+ 1			
,, sm. crater* ...	+·0495	+·0488	+ 7	+·6605	+·6610	− 5			
Piazzi Smyth	−·0417	−·0421	+ 4	+·6674	+·6676	− 2			

The point measured has been the summit of the central mountain where one exists, in other cases the centre of the ring.

Out of the eighty-four differences only five exceed ·001, *i.e.* amount to 1″ (geocentric), twelve more exceed ·0005, the other sixty-seven are all less than half a second of arc.

The test is a severe one, as the points are measured under opposite illuminations, and very different librations. The effect of this is shown in the two columns of residuals, those for ξ, which is more affected by these causes, being considerably greater than those for η. But, if we bear in mind the great uncertainties which have been found in all previous determinations, I think the agreement must be considered most satisfactory.

Table II. gives the corresponding results for those points which were measured on both plates, but were not included in the determination of the orientation. Here, too, the agreement is hardly less satisfactory, though the average discordance in ξ is a little greater, as might have been anticipated, when it is remembered that one cause for rejection was unsuitable illumination.

* Just outside Cassini to the N.E.

Table II.

List of Twenty Points measured on Plates II. and III., but not used in Determining the Orientation.

	ξ_2	ξ_3	$\xi_2-\xi_3$	η_2	η_3	$\eta_2-\eta_3$	Other Observers. ξ	η	Authority
Maginus A*	−·0632	−·0641	+·0009	−·7635	−·7640	+·0005	−·0795	−·7655	Mädler
Licetus, small crater†	+·0232	+·0222	+ 10	−·7286	−·7288	+ 2			
Maurolycus A ...	+·1787	+·1773	+ 14	−·6877	−·6877	0	+·1719	−·6869	Mädler
Stöfler *f*	+·0643	+·0633	+ 10	−·6778	−·6774	− 4			
Walter	+·0139	+·0139	0	−·5469	−·5465	− 4			
Thebit A	−·0787	−·0790	+ 3	−·3677	−·3672	− 5	−·0939	−·3631	Mädler
Arzachael	−·0359	−·0359	0	−·3136	−·3140	+ 4			
„ A	−·0247	−·0247	0	−·3093	−·3092	− 1			
Alpetragius B ...	−·1150	−·1151	+ 1	−·2604	−·2605	+ 1			
Albategnius	+·0652	+·0650	+ 2	−·1958	−·1962	+ 4	+·0679	−·1969	Lohrmann
Halley	+·1000	+·0996	+ 4	−·1390	−·1393	+ 3	+·0970	−·1411	Neison
Hipparchus C ...	+·1414	+·1427	− 13	−·1281	−·1283	+ 2	+·1390	−·1285	Neison
„ L ...	+·1561	+·1566	− 5	−·1188	−·1191	+ 3	+·1523	−·1189	Neison
Horrocks	+·1023	+·1021	+ 2	−·0688	−·0694	+ 6	+·1023	−·0699	Neison
Bode B	−·0530	−·0530	0	+·1522	+·1523	− 1	−·0545	+·1515	Neison
							+·1479	+·2495	Bouvard and Nicollet
Manilius	+·1540	+·1535	+ 5	+·2499	+·2498	+ 1	+·1528	+·2463	Lohrmann
							+·1520	+·2515	T. Mayer
Aristillus S.E. peak ...	+·0173	+·0163	+ 10	+·5547	+·5548	− 1	+·0147	+·5557	Lohrmann
„ N.W. peak ...	+·0199	+·0187	+ 12	+·5572	+·5569	+ 3			
Kirsch	−·0751	−·0758	+ 7	+·6324	+·6328	− 4			
Cassini A	+·0636	+·0635	+ 1	+·6491	+·6495	− 4	+·0551	+·6478	Mädler.

* The central mountain, not the crater.

† A small round crater W. of *f* and *d*

§15. *Comparison with the Results obtained by previous Observers.*

Some of these positions differ considerably from those found by other observers. I may notice especially Maginus A and Thebit A in Table II.

In order to ensure that there has been no mistake with regard to the latter I have looked up the references to it in *Der Mond*. There is a misprint in the index which refers to it as Thebit B, but the description in the text leaves no doubt as to the identity. Its position was measured twelve times; the mean longitude derived from the first nine measures is $-5° 37'$. I suppress the seconds, which are worthless, and the mean from the last three $-6° 28'$. These last three were taken on the same night, and three other formations were also measured three times each on that night. Three out of the twelve measures were rejected because the positions deduced from them were so discordant as to show there must have been some error in the observations, whilst, with one exception only, each of the other nine gave a position further east than any single measure made on any other night. Mädler's two positions for Thebit A are in rectangular coordinates

From the first 9 measures $\xi = -\cdot0913 \quad \eta = -\cdot3605$
From the last 3 measures $\xi = -\cdot1046 \quad \eta = -\cdot3706$

showing a geocentric difference of $12''\cdot4$ in ξ and $9''\cdot4$ in η. This affords a pretty conclusive illustration of the errors to which measurements from the limb are liable.

But perhaps the most surprising result in Table II. is the large discordance in the position of Manilius, this having been considered as exceptionally well determined from 174 measures of Bouvard and Nicollet, made in their investigation of the Moon's physical libration.

I have not found this an easy point to measure, either on the photographs or on the Moon; but the two photographic measures are in close agreement with one another and with the telescopic measures quoted in § 6 (see also Table IV. below), and they are quite irreconcilable with Bouvard and Nicollet's position. It may be noted that while my latitude agrees with Bouvard and Nicollet's my longitude does not differ much from Lohrmann's. His, however, rests on only one determination. T. Mayer measured the point twenty-seven times, and his place is on the whole the nearest to mine.

In addition to the points measured on two plates I have measured sixty other points of the first order on one plate only, some on Plate II., others on III. I do not quote all these measures now, because the object of this paper is not to give definite results, but to call attention to the method and to the promise it holds out. It will, however, be interesting to compare the general results with those of previous observers.

TABLE III.

Comparison of the mean of all points measured with measures of previous Observers.

				Ratio.*	Mean Difference
Sum of 16 positive values of ξ measured by Lohrmann	4·8516	Sum of ξ's of same points from photo. measures	4·8727	1·0043	·0013
" 21 negative " " " " "	6·2676	" " " " " " "	6·2629	·9993	·0002
" 16 positive values of η " " "	5·6264	" η " " " " "	5·6589	1·0058	·0020
" 21 negative " " " " "	6·1058	" " " " " " "	6·1442	1·0063	·0018
Sum of 12 positive values of ξ measured by Mädler	3·8167	Sum of ξ's " " " " "	3·9079	1·0239	·0076
" 28 negative " " " " "	10·0913	" " " " " " "	10·0784	·9987	·0005
" 9 positive values of η " " "	4·7341	" η " " " " "	4·7654	1·0066	·0035
" 31 negative " " " " "	13·2423	" " " " " " "	13·3194	1·0058	·0025
Sum of 11 positive values of ξ measured by Neison	2·6022	Sum of ξ's " " " " "	2·6635	1·0236	·0056
" 14 negative " " " " "	3·6882	" " " " " " "	3·6850	·9991	·0002
" 13 positive values of η " " "	2·4759	" η " " " " "	2·4959	1·0081	·0015
" 12 negative " " " " "	1·9119	" " " " " " "	1·8910	·9890	·0017

* The value given by the photographic measures is always taken as the numerator of this ratio.

It will be seen that my results agree more closely with those of Lohrmann than with those of either Mädler or Neison. On the whole, the new measures place the points further from the centre than the old ones, a result which was anticipated in § 2. With regard to the curious difference noticeable in all three cases between the results for the positive and those for the negative values of ξ, I am not prepared to accept the obvious explanation of an error of centre in the photographic measures for reasons which will be stated in § 17.

It is only with regard to Mädler's measures that I have been able to investigate the details; but I find that, of his 28 points with negative ξ, 6 were measured from the west limb entirely; and another, Pico, was measured five times from each limb.

An examination of the few cases in which Mädler has measured a point sometimes from the east limb and sometimes from the west shows that his tendency is to place the point too far from the limb used. Thus in the case of Pico the five measures from the east limb give a longitude $-9° 7'$, with $\xi = -·1110$; those from the west limb give $-9° 18'$, with $\xi = -·1135$, the difference being ·0025, or 2″·3 (geocentric).

If these seven points are excluded from the table the numbers become, for 21 points:—

Sum of Mädler's values of ξ		9·3400
Sum of photographic values of ξ		9·3979
Giving the ratio ...	1·0062	
And mean difference ...	·0028	

which are in close accordance with the results obtained from the values of η.

This effect may be due to the difference in illumination, a rising sun tending to throw the point measured towards the east; but the matter requires further investigation.

It seems likely that a similar tendency to measure from the west limb rather than the east would be found among other observers. The former measures can be made in our evening, whilst the latter necessitate work in the early morning.

In no case did Mädler systematically measure a point in the west hemisphere from the east limb.

§ 16. *Argument that Absolute Places have really been found.*

The great differences already noted call for some further discussion of the accuracy of my results.

The close agreement between Plates II. and III. shown by Tables I. and II. proves, I think conclusively, that the relative positions are well determined. I will consider a little more closely how far the absolute places can be relied on.

Equations (10) in § 14 may be written

$$\left.\begin{array}{r} 9478(\delta\theta_2-\delta\theta_3)+779\delta\theta_3+41\cdot50=0 \\ -8699(\delta\theta_2-\delta\theta_3)+710\delta\theta_3-42\cdot81=0 \end{array}\right\}$$

from which it appears that the coefficient of $\delta\theta_2-\delta\theta_3$ is twelve times that of $\delta\theta_3$, and consequently that the value of $\delta\theta_2-\delta\theta_3$ is much better determined than are those of $\delta\theta_2$, $\delta\theta_3$ separately; whilst it is upon these latter that the absolute places depend.

But if we take the value $\delta\theta_2-\delta\theta_3=-\cdot00465$, found from these equations, and substitute it in the four equations (8), (9), we have

From (8)	$334\delta\theta_3=1\cdot10$	whence	$\delta\theta_3=\cdot00304$
	$176\delta\theta_3=\ \cdot90$		$\delta\theta_3=\cdot0051$
From (9)	$445\delta\theta_3=1\cdot47$		$\delta\theta_3=\cdot00330$
	$886\delta\theta_3=3\cdot26$		$\delta\theta_3=\cdot00368$

The only one of these which differs sensibly from the final solution $\delta\theta_3=\cdot00331$ is that which depends upon the smallest coefficient.

Now equations (8) are the normal equations obtained from the conditional equations in ξ; equations (9) are similarly deduced from those in η; and as the values of A, E in equations (7), § 11, are nearly unity, whilst those of the other constants are small, it follows that the values of ξ depend chiefly upon the measures of x, those of η upon the measures of y, and therefore the two groups are to a large extent independent. The agreement between the values of $\delta\theta_3$ from these two groups shows that we are finding a real value, and not merely a chance mean.

It may be noted also that the probable error of $\delta\theta_3$ from the complete solution is only $0'\cdot9$.

These considerations seem to me to justify the conclusion that the orientation has been obtained absolutely within close limits.

§ 17. *Final Consideration of the Accuracy attained.*

The results in Table III. also raise the question whether the scale and centre have been accurately obtained for the photographic plates.

To test this I give in Table IV. a list of points measured on the Moon itself as explained in § 5, and also on the photographs. To my own measures I have again added, for ready comparison, those of other observers.

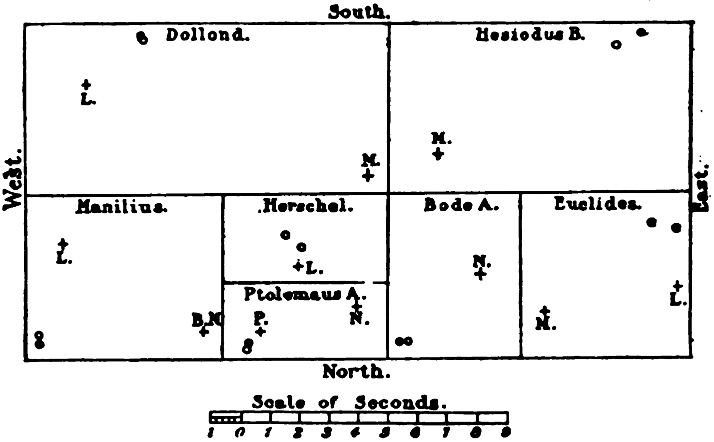
The scales in these two cases are entirely independent, that for the measures made at the telescope depending on the value adopted for my micrometer screw, which was determined from a series of measures of differences of declination of stars in the *Pleiades*, compared with the results of Elkin's triangulation.

TABLE IV.

Comparison of Points measured on the Photographs and at the Telescope.

	From Photographs. ξ	η	At the Telescope. ξ	η	By other Observers. ξ	η	
Hesiodus B	−·2681	−·4557	−·2672	−·4553	−·2608	−·4515	Mädler
Dollond	+·2459	−·1818	+·2458	−·1817	+·2477	−·1801	Lohrman
					+·2377	−·1768	Mädler
Ptolemaus A	−·0140	−·1479	−·0139	−·1477	−·0144	−·1483	Pritchard
					−·0168	−·1492	Neison
Euclides	−·4896	−·1279	−·4887	−·1281	−·4896	−·1258	Lohrman
					−·4850	−·1249	Mädler
Herschel	−·0375	−·0986	−·0370	−·0990	−·0374	−·0979	Lohrman
Bode A *	−·0200	+·1570	−·0203	+·1570	−·0229	+·1547	Neison
Manilius	+·1537	+·2499	+·1537	+·2496	+·1479	+·2495	Bouvard Nicoll
					+·1528	+·2463	Lohrman
					+·1520	+·2515	T. Mayer

These results are also shown in the following diagram :—



● Position found from Photograph.
o „ „ at Telescope.
+ „ „ by other Observers.

B.N.—Bouvard and Nicollet. L.—Lohrmann.
M.—Mädler. N.—Neison. P.—Pritchard.

The sum of the positive values of η is from the photographs		1·0119
„ „ „	at the telescope	1·0118
The sum of the negative values of η is from the photographs		4·069
„ „ „	at the telescope	4·066

* Measured on one night only.

So far as can be inferred from such a small number of measures this justifies the conclusion that both the scale and the ordinate of the centre have been correctly found.

But there is a mean difference of ·0004 between the negative values of ξ, the photographic values being numerically the greater. This, in conjunction with the fact that the ξ of Mösting A given in Table I. is $-$·0906, whilst Franz's value is $-$·0900, points to the conclusion that the centre has been placed about half a second too far west in the photographs. It will be remembered that it was noted in § 13 that some difficulty had been found in determining this abscissa.

Moving the centre to the east would numerically decrease the negative values of ξ, and accentuate the difference noted in Table III. between the results for positive and negative values. It is on this ground that I hesitate to accept an error in my position of the centre as an explanation of that difference.

With regard to this error of centre, it would have been possible to introduce corresponding terms into the conditional equations of § 14, but this would have necessitated the solution of eighty-four equations for six unknowns. Something of this sort may be desirable in the final work, but I did not feel that it was necessary in a preliminary investigation, which, for all I knew at the time, might end in a complete failure.

§ 18. *Conclusion.*

I do not think that the limit of accuracy of which these photographic measures are capable has yet been attained. In the first place, by measuring the original negatives I hope to find less difficulty in seeing the *réseau*, and to get better definition of some points which in the copies are lost in glare. Secondly, by the use of a *réseau* covering the whole limb, I hope to get a better determination of the coordinates of the centre and of the radius. Professor Turner has already procured for me a copy of one of sufficient size through the kindness of Mr. Franklin Adams.

M. Loewy has sent four more negatives, two of which show the zone already measured under yet different conditions. These I propose to treat in the same way as Plates II. and III. have already been dealt with, and so to obtain a set of definite values for the points shown on all four plates. When this has been done the constants for these plates can be finally determined, and the positions of all points shown on them obtained, with accuracy of the same order as those already measured.

This will greatly facilitate the determination of the constants for other plates, and of the positions of all points shown on them.

When once these constants have been found, the reduction of the measures is very simple, as may be seen from the following example :—

Reduction of Measures of Pitiscus A made on Plate II.

	x	y
Measured values of coordinates in terms of *réseau* intervals	10·835	24·560
Coordinates of centre of disc	17·345	13·752
Coordinates referred to centre of disc	+ 6·510	− 10·808
Refraction correction (as in § 12)	2	3
Coordinates corrected for refraction	+ 6·512	− 10·811
Multiply by ·063432 the reciprocal of Moon's radius.		
Coordinates in terms of Moon's radius	+ ·4131	− ·6858
Approximate value of $r = ·801$		
" " $z = ·599$		
Value of $\sin s' = ·00440$.		
∴ $z \sin s' = ·00264$.		
$r^2 \sin^2 s' = ·00002$.		
Correction for finite distance (as in § 8)	11	18
Final values of coordinates	+ ·4120	− ·6840
Corresponding value of $z = +·6020$		

The standard coordinates are found from

$$\xi = Ax + By + Cz.$$
$$= ·9786 \times (+·4120) + ·1863 \times (-·6840) + ·0876 \times (+·6020).$$
$$= +·3285.$$
$$\eta = Dx + Ey + Fz.$$
$$= -·1840 \times (+·4120) + ·9823 \times (-·6840) - ·0341 \times (+·6020).$$
$$= -·7682.$$

The measures have been made with one of Professor Turner's star plate micrometers belonging to the Oxford University Observatory. The glass scale is admirably adapted for work on the Moon, where it very frequently happens that one side of a crater is lost in glare. If the crater is circular and near the centre of the disc, the scale has only to be placed so that the readings of the points at which three of the arms cut the walls are equal, when the intersection must be at the centre of the circle. Other cases are not all so simple, but the help afforded by reading the points at which the arms cut the walls is always considerable. A crater has not been measured unless the greater part of the ridge is shown, the rest can be supplied mentally, and by determining the centre from this the confusing effects of light and shade upon the floor are avoided.

It only remains for me to express my thanks in the first place to M. Loewy for his great kindness in sending the photographs. The beauty of the negatives now taken at the Paris Observatory is too well known to need any comment, and it is little better than a truism to say that it is only upon photographs of the best definition that accurate measures are possible.

That I have been able to accomplish as much as I have in the time at my disposal has been due to the skill and the care with which Mr. Bellamy has overcome for me all the difficulties of

manipulation; whilst the extent of my obligation to Professor Turner is very far indeed from being covered by the definite acknowledgments I have already made.

Some Suggestions for the Explicit Use of Direction Cosines or Rectangular Coordinates in Astronomical Computations. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. Until the introduction of the photographic method, the simple computations of astronomy could be fairly regarded as settled in form. The form depended essentially on the large use of meridian observations, which determine R.A. and N.P.D. independently, and thus all computations and catalogues are arranged in terms of R.A. and N.P.D. Tables of the planets, which are most conveniently expressed in latitude and longitude, and are so expressed in the first instance, are converted into terms of R.A. and N.P.D. for the use of observers.

2. But even independently of photography some inconveniences attending the use of these particular coordinates have made themselves felt. The neighbourhood of the pole is always a difficulty, and calls for some modification of the ordinary processes. Fabritius proposed in *Ast. Nach.* Nos. 2072–3 to use the coordinates

$$x = \sin p \cos \alpha \qquad y = \sin p \sin \alpha$$

in the neighbourhood of the pole, where α, p are the R.A. and N.P.D. of a star; and he showed that the use of these rectangular coordinates considerably simplifies the calculation of precession and nutation for polar stars. His x and y may be thus regarded. Draw a tangent plane to the sphere at the pole, and orthogonally project stars from the sphere on to this plane by lines parallel to the Earth's axis; then (x, y) are the Cartesian coordinates of the projection referred to axes in this plane.

3. In connection with the measurement and reduction of photographic plates I have urged the advantages of using "standard coordinates" which are also the Cartesian coordinates of a star supposed projected on a tangent plane to the celestial sphere; but in this case the projection is not orthogonal; it is by lines radiating from the centre of the sphere. For a plate with centre at the pole the "standard coordinates" would be

$$\xi = \tan p \cos \alpha \qquad \eta = \tan p \sin \alpha$$

as compared with Fabritius's

$$x = \sin p \cos \alpha \qquad y = \sin p \sin \alpha$$

4. Other projections on the tangent plane might be made. Thus the well-known stereographic projection would be represented by

$$X = 2 \tan \frac{p}{2} \cos \alpha \qquad Y = 2 \tan \frac{p}{2} \sin \alpha$$

and it is possible that these coordinates or yet others may be found useful in some department of astronomical work. But without following generalities further in this direction, we may notice that both Fabritius's and standard coordinates are closely related to direction cosines. If the three direction cosines of a star be

$$l=\sin p\cos a \qquad m=\sin p\sin a \qquad n=\cos p$$

then we have for Fabritius coordinates

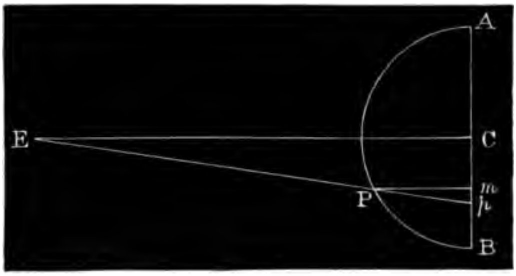
$$x=l \qquad y=m$$

and for standard coordinates

$$\xi=\frac{l}{n} \qquad \eta=\frac{m}{n}$$

Now this suggests that the more explicit use of direction cosines in our computations may be attended with advantages; and the present paper is written with the object of calling attention to this point by two particular examples.

5. The first example is that in which we are dealing with



positions of objects on the surface of the Sun or Moon. Let C be the centre of the Moon; E, the spectator on the Earth. He sees any point P on the surface of the Moon projected on the plane AB, as at *p*. Now E is at a great distance, and hence EP is *nearly* parallel, though not quite, to EC. By a slight correction to C*p* we can find the orthogonally projected coordinates of P, and are thus prepared for the use of direction cosines in the reductions. The correction required is

$$\begin{aligned} pm &= \mathrm{P}m \tan m\mathrm{P}p \\ &= \sqrt{\mathrm{CB}^2-\mathrm{C}m^2}\ .\ \mathrm{C}p\ .\ /\mathrm{CE} \\ &= \frac{\mathrm{CB}}{\mathrm{CE}}\left\{1-\left(\frac{\mathrm{C}m}{\mathrm{CB}}\right)^2\right\}^{\frac{1}{2}}\mathrm{C}p \end{aligned}$$

Here CB/CE is the angular radius of the Moon in circular measure—about ·005. The remainder of the expression has a maximum value when $\mathrm{C}m^2=\frac{1}{2}\mathrm{CB}^2$, nearly; and thus the maximum value of the correction is

$$\tfrac{1}{2}\times{\cdot}005\times 16'=2''{\cdot}5, \text{ say.}$$

Hence a small table suffices to give the fraction by which we must diminish Cp.

If, then, we measure on the Moon, or on a photograph of the Moon, rectangular coordinates x' and y' from the centre of the disc, and expressed in terms of the Moon's radius, and with $\sqrt{x'^2+y'^2}$ as argument, take out from the table the appropriate reducing factor, we can get x, y, two of the direction cosines of the point, and can then find $z=\sqrt{1-x^2-y^2}$.

6. These (x, y, z) are coordinates of the point with axis of z directed to the centre of the Earth and axes of x and y at right angles to it, with some orientation depending upon the way in which the measures were made. Let now (X, Y, Z) be direction cosines of the point referred to chosen axes fixed in the Moon. Then by the properties of direction cosines we know that

$$\xi=a_1x+a_2y+a_3z$$
$$\eta=b_1x+b_2y+b_3z$$
$$\zeta=c_1x+c_2y+c_3z$$

with the reciprocal relations

$$x=a_1\xi+b_1\eta+c_1\zeta$$
$$y=a_2\xi+b_2\eta+c_2\zeta$$
$$z=a_3\xi+b_3\eta+b_3\zeta$$

where $(a_1, a_2, a_3 \ldots c_3)$ are a system of direction cosines expressing the relationship of the two systems. We may calculate these coefficients from our knowledge of the Moon's librations; or, if we know the coordinates (X, Y, Z) of certain points on the Moon, of which we determine the (x, y, z) by measures, we can find the coefficients $(a_1 \ldots c_3)$ by substituting for these known points in the equations above given.

7. Again, our measures may only give us x and y, affected with certain errors—those due to refraction, or defective centring of the plate, or defective scale value, or orientation. We shall thus get, not x and y, but two linear functions of them and z, viz.

$$x_0=\mathrm{A}x+\mathrm{B}y+\mathrm{C}z+\mathrm{D}$$
$$y_0=\mathrm{E}x+\mathrm{F}y+\mathrm{G}z+\mathrm{H}$$

where the coefficients AB . . . H are not altogether known, though certain parts of them, such as that due to refraction, may be calculated. Without troubling to make this calculation, however, we see from the linearity of all the above relations that we may write

$$x_0=a\xi+b\eta+c\zeta+d$$
$$y_0=e\xi+f\eta+g\zeta+h$$

so that the measures x_0 and y_0 (corrected to orthogonal projection of course) are expressible as linear functions of the coordinates (ξ, η, ζ). If, then, we know the (ξ, η, ζ) of a certain number of measured points we can find these eight constants of the plate $(a, b \ldots h)$, and then using them for any other measured point we can find the (ξ, η, ζ) from the two equations of the above form combined with (ξ, η, ζ).

8. Of this method Mr. Saunder (see p. 184) has made trial in measuring some beautiful lunar photographs, kindly lent by the Director of the Paris Observatory (M. Loewy). He found the method unsatisfactory, however, because there are, in fact, at present not enough points on the Moon whose positions are well determined. Mr. Saunder has therefore devised (see p. 185) an elegant method of his own, which bids fair to give us excellent positions of a number of points; and then it is possible that he may return to this method for finding the coordinates of other points.

9. But there is a point of detail in which the method requires improvement, viz. it is rather troublesome to solve the three equations

$$a\xi+b\eta+c\zeta=x_0-d=x_1, \text{ say}$$
$$e\xi+f\eta+g\zeta=y_0-h=y_1, \text{ say}$$
$$\xi^2+\eta^2+\zeta^2=1$$

(of which the third is a quadratic) for every point. The constants d and h are quickly subtracted, of course, and may be disregarded. To avoid the solution of the quadratic I suggest the following procedure:—

But for refraction and accidental errors the constants $a, b \ldots g$ would fulfil the relations

$$a^2+b^2+c^2=1,\ e^2+f^2+g^2=1,\ ae+bf+cg=0$$

and then putting

$$1-a^2-e^2=p^2,\ 1-b^2-f^2=q^2,\ 1-c^2-g^2=r^2,\ 1-x_1{}^2-y_1{}^2=z_1{}^2$$

we should have

$$\xi=ax_1+ey_1+pz_1$$
$$\eta=bx_1+fy_1+qz_1$$
$$\zeta=cx_1+gy_1+rz_1$$

All these calculations could be quickly made, especially with an arithmometer and a table of squares.

Owing to refraction and accidental errors these relations are only approximately fulfilled. But if instead of x_1 and y_1 we write

$$x_1+\lambda x_1+\mu y_1 \text{ and } y_1+\mu x_1+\nu y_1,$$

where λ, μ, ν are small, we can determine (λ, μ, ν) so as to fulfil the corresponding relations *exactly*. We have, in fact,

$$(a+a\lambda+e\mu)^2+(b+b\lambda+f\mu)^2+(c+c\lambda+g\mu)^2=1$$
$$(e+a\mu+e\nu)^2+ \quad . \quad . \quad . \quad . \quad . \quad =1$$
$$(a+a\lambda+e\mu)(e+a\mu+e\nu)+ \quad . \quad . \quad . \quad =0$$

Put $\quad 1-(a^2+b^2+c^2)=A,\ 1-(e^2+f^2+g^2)=C,\ ae+bf+cg=-B,$

where A, B, C are at least of the same order as λ, μ, ν; and neglect in the first instance squares of small quantities. The equations become

$$2\lambda=A,\ 2\nu=C,\ 2\mu=B,$$

and the test whether this approximation is sufficient is that the corrected values of the coefficients should sensibly fulfil the above relations. If not, the process may be repeated, and new values of λ, μ, ν found. But since refraction is small, one approximation should suffice. Putting, then,

$$\alpha=a+a\lambda+e\mu \quad \beta=b+b\lambda+f\mu \text{ \&c.}$$

and $\quad x_2=x_1+\lambda x_1+\mu y_1,\ y_2=y_1+\mu x_1+\nu y_1,\ z_2{}^2=1-x_2{}^2-y_2{}^2,$

so that α, β and also x_2, y_2, z_2 can be found without much trouble, we have

$$\xi=\alpha x_2+\epsilon y_2+\pi z_2$$
$$\eta=\beta x_2+\zeta y_2+\kappa z_2$$
$$\zeta=\gamma x_2+\eta y_2+\rho z_2$$

and thus ξ, η, ζ can be found simply.

10. A second example of the explicit use of linear formulæ of this kind is afforded by the computations of the effect of precession and nutation. The advantages have been partially pointed out by Fabritius and others. In *Ast. Nach.*, No. 3610, recently published, Dr. W. Ebert considers the special application of Fabritius's formulæ to stars within 20′ of the pole. But I venture to think that the advantages of the *general* application of such formulæ have been hitherto overlooked. Precession and nutation simply change the three axes of reference, so that if (x, y, z) are the direction cosines of a star for one date and (ξ, η, ζ) those for another, we have

$$\xi=a_1x+a_2y+a_3z$$
$$\eta=b_1x+b_2y+b_3z$$
$$\zeta=c_1x+c_2y+c_3z$$

where the constants $a_1, a_2, a_3 \ldots c_3$ are connected by the six well-known relations. Since the axes of reference change slowly

a_1, b_2, c_3 are nearly unity, and the others nearly zero, for any moderate interval. We may write, in fact,

$$\begin{aligned}\xi - x &= \alpha x + a_2 y + a_3 z\\ \eta - y &= b_1 x + \beta y + b_3 z\\ \zeta - z &= c_1 x + c_2 y + \gamma z\end{aligned}$$

and then the coefficients on the right are all small, and only approximate values of x, y, z are needed on the right.

11. Some of the coefficients are of the first order and some of the second. To show their general character let us neglect the slow motion of the ecliptic and consider the pole of the equator (axis of z or ζ) revolving round the fixed pole of the ecliptic with angular velocity q. Let x, y, z be the coordinates of a star at epoch $t=0$, and ξ, η, ζ the coordinates at time $t=t$.

The pole of the ecliptic has the same coordinates in both systems, viz.

$$\begin{array}{lll} x=0 & y=-\sin\omega & z=\cos\omega\\ \xi=0 & \eta=-\sin\omega & \zeta=\cos\omega\end{array}$$

Thus
$$\begin{aligned}0 &= -a_2\sin\omega + a_3\cos\omega\\ -\sin\omega &= -b_2\sin\omega + b_3\cos\omega\\ \cos\omega &= -c_2\sin\omega + c_3\cos\omega.\end{aligned}$$

Therefore
$$\tan\omega = \frac{a_3}{a_2} = \frac{b_3}{b_2 - 1} = \frac{c_3 - 1}{c_2}.$$

Multiply the numerators and denominators by a_3, b_3, c_3 respectively and add. Each ratio is found equal to $\frac{1-c_3}{-b_3}$ and this shows that $b_3 = c_2$. The same result is obtained if we multiply by a_2, b_2, c_2. But from multiplying by a_1, b_1, c_1 we get each ratio equal to $\frac{c_1}{b_1}$; whence $c_1 = b_1 \tan\omega$. It will be found that we can now express all the quantities in terms of c_3. Thus

$$\begin{aligned}c_2 &= (c_3 - 1)\cot\omega\\ c_1^2 &= 1 - c_2^2 - c_3^2\\ b_1 &= c_1\cot\omega\\ b_3 &= (c_3 - 1)\cot\omega\\ b_2^2 &= 1 - b_1^2 - b_3^2\end{aligned}$$

and so on. To find c_3 we must refer to the spherical triangle formed by E, the pole of the ecliptic, and P_1 P_2, the two poles of the equator at the different epochs. In this triangle

$$\begin{aligned}c_3 = \cos P_1P_2 &= \cos P_1E\cos P_2E + \sin P_1E\sin P_2E\cos E\\ &= \cos^2\omega + \sin^2\omega\cos qt.\end{aligned}$$

Hence
$$c_2 = \sin\omega\cos\omega\,(\cos qt - 1)$$
$$c_1 = \sin\omega\sin qt$$
$$b_1 = \cos\omega\sin qt.$$

We may express the values by the following scheme :—

	x	y	z
ξ	$\cos qt$	$-\cos\omega\sin qt$	$-\sin\omega\sin qt$
η	$\cos\omega\sin qt$	$\cos^2\omega\cos qt + \sin^2\omega$	$\cos\omega\sin\omega\,(\cos qt - 1)$
ζ	$\sin\omega\sin qt$	$\cos\omega\sin\omega\,(\cos qt - 1)$	$\sin^2\omega\cos qt + \cos^2\omega.$

12. Now qt is a small quantity. In a century $qt = 5000''$ approximately, or, say, ·025 in circular measure. Thus we may exhibit the approximate values of powers of qt for different periods as follows :—

	10 yrs.	50 yrs.	100 yrs.	300 yrs.
qt	·0025	·0125	·025	·075
$(qt)^2$	·0000063	·0001563	·000625	·005625
$(qt)^3$	·0000000	·0000020	·0000156	·0004188
$(qt)^4$	...	·0000000	·0000004	·0000316
$(qt)^5$	...	...	·0000000	·0000024

Hence, if we are applying precessions for ten years, we can neglect the third power of qt; for fifty years the fourth power; and, indeed, up to one hundred years we can neglect the fourth power, which, as we shall see, is generally multiplied by a small fraction.

13. For simplicity let us first neglect $(qt)^3$—*i.e.* consider precessions for moderate periods comparable with ten or twenty years. Then putting $qt\cos\omega = s$, $\tan\omega = r$; since $\cos\omega = \cdot 91$, s is less than qt, and its powers converge more rapidly. Also powers of $r (= 0\cdot 4)$ converge quickly. The scheme of transformation now becomes

	x	y	z
ξ	$1 - \frac{1}{2}(1 + r^2)s^2$	$-s$	$-rs$
η	$+s$	$1 - \frac{1}{2}s^2$	$-\frac{1}{2}rs^2$
ζ	$+rs$	$-\frac{1}{2}rs^2$	$1 - \frac{1}{2}r^2s^2$

Since s is proportional to the first power of the time, and s^2 to the second, we see that this scheme gives in a compendious form both the precessions and secular variations of x, y, z—viz. the precessions are

in x, $\quad -(y + rz)s$

in y, $\quad +x \,.\, s$

in z, $\quad +xr \,.\, s$

and the secular variations are

$$\begin{array}{ll} \text{in } x & -\tfrac{1}{2}x(1+r^2)s^2 \\ \text{in } y & -\tfrac{1}{2}(y+rz)s^2 \\ \text{in } z & -\tfrac{1}{2}r(y+rz)s^2 \end{array}$$

14. Similarly, the additional terms of the third and fourth orders are readily written down as follows, omitting a common factor, $\frac{1}{24}s^3(1+r^2)$, for convenience in writing :—

	x	y	z
ξ	$s(1+r^2)$	4	$4r$
η	-4	$+s$	$+sr$
ζ	$-4r$	$+sr$	$+s\,.\,r^2$

The terms of the third order are all less than $\frac{1}{8}(qt)^3$, and only begin to affect the seventh place of decimals after about thirty years.

The largest term of the fourth order is $\frac{1}{24}(qt)^4$, and does not affect the seventh place for more than a century.

15. Since the ecliptic is slowly moving, terms must be added to these coefficients, depending on the motion of the ecliptic ; but these will be of a higher order still ; and enough has been said to show the general character of the coefficients. Returning to the general form for them

$$\begin{aligned} \xi &= a_1x + a_2y + a_3z \\ \eta &= b_1x + b_2y + b_3z \\ \zeta &= c_1x + c_2y + c_3z \end{aligned}$$

Suppose (x, y, z) refer to any standard epoch—say 1900·0. Then, to find the coordinates for any other epoch, we want the nine coefficients, $a_1, a_2 \ldots c_3$. Now it would not be a difficult matter to tabulate these for every year for three hundred years—say, from A.D. 1700 to 2000 (all we are likely to want at present)—and we should then have the means of bringing up to 1900·0 *accurately* any stellar positions referred to another epoch. There is no special difficulty about polar stars ; the formulæ never become less simple in any part of the celestial sphere ; and the labour of multiplication can be quickly performed with an arithmometer, or in many cases by Crelle's Tables, since the coefficients are small.

16. To reduce from one epoch to another when neither is 1900·0, we must form nine new coefficients ; but these are readily formed when we have those connecting both epochs with 1900·0. Thus let (ξ, η, ζ) refer to one epoch, as above, and (X, Y, Z) to another, and let

$$X = A_1x + A_2y + A_3z, \text{ \&c.}$$

so that $$x = A_1X + B_1Y + C_1Z, \text{ \&c.}$$

according to the usual inversion of direction cosines.

Then $\xi = a_1x + a_2y + a_3z$

$$= (a_1A_1 + a_2A_2 + a_3A_3)X + (a_1B_1 + a_2B_2 + a_3B_3)Y + (a_1C_1 + a_2C_2 + a_3C_3)Z$$

with similar equations for η and ζ, and the law of formation of the coefficients is obvious.

17. *Aberration.*—The use of direction cosines does not always simplify the formulæ, however, and we may take aberration as an instance where there is no great simplification. The effect of aberration is well known to be precisely similar to that of parallax, viz. a displacement of the observer in a given direction. If the direction be defined by the cosines (l, m, n), and k be the coefficient of aberration, the centre of the sphere is virtually moved to the point $(-kl, -km, -kn)$. Thus the coordinates of a point (x, y, z) become

$$p(x + kl),\ p(y + km),\ p(z + kn),$$

p being a constant introduced in order that the sum of the squares may remain unity; *i.e.*

$$p^2 + 2p^2k(ln + my + nz) + p^2k^2 = 1$$

Now $k = 20''\cdot5$ and $k^2 = 0''\cdot002$, which is insensible in practice.

Thus neglecting k^2, we have

$$p = 1 - k \cos\theta$$

where $\cos\theta = lx + my + nz$, so that θ is the "Earth's Way," the angle between the direction of the star and that of the Earth's motion; and to the first order of k we have for the increments of x, y, z due to aberration

$$k(l - x\cos\theta),\ k(m - y\cos\theta),\ k(n - z\cos\theta).$$

Thus the increment of any coordinate x due to precession, nutation, and aberration, is

$$kl + a_1x + a_2y + a_3z - kx(lx + my + nz),$$

and as regards the calculation of star-corrections, we do not appear to gain anything by the use of direction cosines.

18. It may be remarked incidentally that the effect of aberration on "standard coordinates"

$$\xi = \frac{x}{z} \text{ and } \eta = \frac{y}{z}$$

is to change them into

$$\xi^1 = \frac{x + kl}{z + kn} \text{ and } \eta^1 = \frac{y + km}{z + kn},$$

the common factor p disappearing in the division and leaving only the constants (for all stars) kl, km, kn. When we are dealing with a small photographic plate for which z is nearly unity, we may put $z+kn=z(1+kn)$, and $kl/(z+kn)=kl$,
and thus $\xi'=\xi(1-kn)+kl.$

There is thus a displacement of the centre by the quantities (kl, km) and a change of scale, ξ and η being both multiplied by $(1-kn)$. This result is derived in another way in *Monthly Notices*, vol. liv. p. 20.

Summary.

The present paper points out the advantages of using direction cosines or rectangular coordinates in certain astronomical computations, instead of curvilinear coordinates.

(*a*). In mapping the surface of the Sun or Moon, observations can be easily corrected so as to give us an orthogonal projection of the surface on a diametral plane : which is the same as giving two of three direction cosines. The third can be easily found, and then the transformation to any other axis is made by linear formulæ.

(*b*). In applying precession for long periods to star places, the formulæ in terms of direction cosines are very simple, and a small amount of tabulation would render the accurate reduction of one catalogue to another a simple matter.

The Extra-Equatorial Currents of Jupiter in 1899. By Rev. T. E. R. Phillips.

Despite the southern declination of *Jupiter* in 1899, an immense amount of detail was visible on the planet's surface, and numerous observations have been received from several observers, which have enabled the rotation periods of the surface material in various latitudes to be determined with, it is believed, considerable accuracy. The writer secured a large number of transits of spots during the earlier and intermediate months of the apparition. Mr. Denning, most fortunately, was able to pursue his observations very late—in some cases up to the middle of September; Mr. A. S. Williams has forwarded a large and valuable series of transits; and, in addition to these, much assistance has been derived from the figures of Messrs. Gledhill, Antoniadi, and J. Comas Solà, of Català, Spain (the observations of the latter being published in *Astronomische Nachrichten*, No. 3596, Band 150). Many of the spots have thus been followed for considerable periods of time (in some cases for more than seven months), and in the majority of cases the observations are so numerous and so accordant as to make the question of identi-

-fication quite certain. It may be well to state here that those spots of which the observations admit of any reasonable doubt have been carefully excluded from this discussion.*

The writer wishes to draw special attention to the altogether abnormal velocity exhibited by several spots on the N. tropical zone.

The rotation periods have been obtained in nearly every case by comparing a few observations at the beginning of the series with a few at the end, and the adopted value for each spot has been tested by working out the residuals for all the observations obtained.

All the longitudes in this paper are calculated according to System II. of Mr. Crommelin's ephemeris.

The zero meridian of this system has a daily rate of $870^{\circ}\cdot27$, which corresponds to a rotation period of $9^{h}\ 55^{m}\ 40^{s}\cdot63$.

The observations are so numerous that it is impossible to give them in detail. They are therefore (with the exception of those relating to the red spot) presented in chart form.

These charts are so arranged as to show the observed longitudes of the spots, the dates of the observations, and the observers by whom the transits were obtained.

The following is the explanation of the symbols employed :—

Dark spot.	White spot.	Observer.
▮	ǁ	Antoniadi.
▲	△	Denning.
◆	◇	Gledhill.
●	○	Phillips.
▼	▽	Solà.
■	□	Williams.

Though necessarily wanting in the accuracy of figures, it is hoped that the charts will have the advantage of enabling the reader

(1) To judge of the correctness or otherwise of the identifications;

(2) To see at a glance to what extent in each case the adopted period (indicated by the straight line drawn through the observations) really represents the mean motion of the spot; and

(3) To note readily the various fluctuations of velocity which many of the spots undoubtedly exhibit.

In the tables in which the spots are summarised, and in the second column, the letters D and W denote *dark* and *white* spots respectively.

* See, however, discussion of S. tropical spots.

The following abbreviations are also employed in this discussion :—

N.N.T.B.=north north temperate belt.
N.T.B.=north temperate belt.
S.T.B.=south temperate belt.
S.S.T.B.=south south temperate belt.
N.E.B.=north equatorial belt.
R=rotation period.
p=preceding.
f=following.

1. *Northern Spots.* Approx. lat. $+24°$ to $+33°$.

Included under this head are spots which appeared on the N.N.T.B. and, later in the apparition, on the N.T.B. The former of these belts was fairly conspicuous throughout the apparition, and almost invariably seen double. On the other hand, the N.T.B. was for some months practically invisible. Towards the middle of April the writer traced it as an exceedingly feeble line from about λ 145° to about λ 290°, where it appeared to merge into the N.N.T.B. Later still a few dusky streaks made their appearance, but being ill-defined in character their observation was a matter of some difficulty.

Several transits of spots in about lat. $+25°$ have come to hand, but their identifications are in nearly every case so doubtful that it has been thought better to omit them rather than introduce an element of uncertainty into the results. In consequence only one spot on the N.T.B. has been included in this discussion.

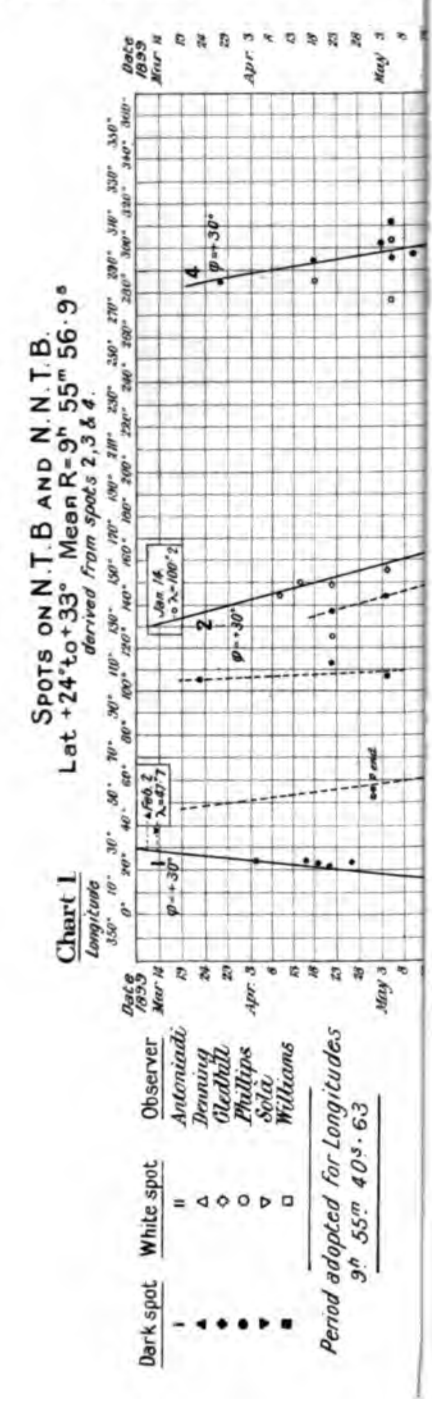
The spots on the N.N.T.B. (lat. $+30° \pm$) were more numerous and more pronounced, though their positions on the disc, combined with the tilt of the N. hemisphere away from the Earth and the planet's considerable S. declination, caused much difficulty in accurately determining the time of their central meridian transits. It is therefore only to be expected that the observations should show some discordances.

The dark spots frequently appeared double, both components of the belt being intensified and united by dusky shadings, which, according to Mr. A. S. Williams, projected as faint streaks beyond the belt in a N. and S. direction.

In a few places the writer observed distinct white spots, which either indented the N.N.T.B. on its S. edge or formed complete rifts through the belt. These white spots seemed to require good seeing conditions to be satisfactorily dealt with, and only one was sufficiently well observed to be included in this paper.

In 1898 two dark streaks on the N.N.T.B. gave a mean rate for this latitude of $9^h\ 55^m\ 52^s{\cdot}0$ (*Monthly Notices*, 1898 December). In the present year the mean derived from four spots for the zone comprised within about lat. $+24°$ and lat. $+33°$ was

$$9^h \quad 55^m \quad 50^s{\cdot}6.$$



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The spots, however, did not move at anything like a uniform rate. A white spot which formed a complete break in the N.N.T.B. indicated a period of $9^h\ 56^m\ 1^s{\cdot}5$, which was longer than the period of any other spot of which the identification was beyond doubt. On the other hand there was a remarkable spot on the N.N.T.B., which, between the beginning of April and the end of July, exhibited the abnormally short period for this latitude of

$$9^h\ 55^m\ 32^s{\cdot}0.$$

It is probable that this rapidly moving spot was quite an isolated case. It therefore seems better in giving the average value for this latitude to take the mean of the three spots which are fairly accordant, and appear to represent the true motion of the surface material in this region of the planet.

The figures then are

$$R = 9^h\ 55^m\ 56^s{\cdot}9.$$

Table of Spots (*see* Chart I., Plate 5).

No.	Character of Spot.	Period of Observation.	No. of Observations.	Rotation Period.	Remarks.
		Days		h m s	
1	D	114	24*	9 55 32·0	On N.N.T.B. Small and well defined at first, more diffused later.
2	W	139	6	9 56 1·5	Break through N.N.T.B. Well seen in good air.
3	D	58	12	9 55 54·2	On N.T.B.
4	D	112	18	9 55 54·9	Diffused condensation of N.N.T.B.

The approximate lat. (ϕ) of the spots discussed is marked on the chart.

2. *The North Tropical Zone.* Approx. lat. $+11°$ to $+18°$.

Beyond all question this was the most remarkable region of the planet in 1899. It will be remembered that several dark spots were seen on this zone in 1898, strung like beads on a very narrow line a little to the N. of the north equatorial belt.

* There is good reason for believing that the following two transits also refer to this spot:

1899 Feb. 2 at $19^h\ 9^m$ $\lambda = 47{\cdot}7°$ (observed by Mr. Denning), and
,, Mar. 13 at $16^h\ 3^m$ $\lambda = 38{\cdot}3°$ (observed by Mr. Williams).

Comparing Mr. Denning's transit of February 2 with that of July 27, we get a mean period of

$$9^h\ 55^m\ 29^s{\cdot}8.$$

As, however, this period does not accord so well with that of the rest of the observations, and the two transits above mentioned stand as it were alone, and may possibly be identified differently (see Chart I.), it is, perhaps, better to compute the velocity of the spot from the transits secured between the beginning of April and the end of July as above.

Three of these spots were sufficiently dark and conspicuous to be thoroughly well observed, and from these Mr. Denning found a mean rotation period of $9^h\ 55^m\ 26^s{\cdot}3$. When the planet was observed by the writer at the end of 1898 December, it was at once noticed that in certain longitudes the north equatorial belt (which had become markedly broader) was much disturbed and broken up along its N. edge by a series of light and dark spots. It appeared as if the dark material of the belt had extended so far N. as to join in many places the narrow line on which the dark spots of the previous apparition had been seen. On subsequent occasions, however, when the seeing was really good, this line was distinctly visible, but the N. edge of the great N. belt had undoubtedly advanced, as the N. tropical spots appeared sometimes (in poor seeing) in contact with, and at other times distinctly separated from, the belt. By the middle of March the observations secured were sufficiently numerous to show that the majority of the spots were moving at a distinctly slower rate than in 1898. But a surprising fact was soon observed. Attention was called by the writer in the *English Mechanic* (No. 1780, letter 42,347) to a dark N. tropical spot which showed an altogether abnormal rate of motion. Later on, other spots made their appearance which exhibited a similar rapidity of movement, and on working out the final results it was found that whereas the surface material in one region of the zone was rotating at a mean rate of $9^h\ 55^m\ 33^s{\cdot}9$ (which is about normal for this latitude), the other part was rotating in $9^h\ 55^m\ 15^s{\cdot}3$. Differences of velocity in different longitudes are of course not infrequent, but it is most remarkable that any N. tropical spots should move with such rapidity as those to which reference has just been made; in fact, such a rate of motion has never—to the writer's knowledge—been recorded of any spots in this latitude before.

The sharpness of the boundary line between these two regions was no less striking, for the rapidly moving material appeared to be strictly confined within about λ 140° and λ 260°. Spots starting immediately W. of this latter point showed a remarkable velocity from their commencement, and spots on approaching λ 140° were either quenched and died out, or they were suddenly checked and made to conform to the slower rate of the spots preceding them.

A large number of spots in this zone were sufficiently well observed to enable reliable periods to be worked out.

Mean R of all the spots discussed $= 9^h\ 55^m\ 28^s{\cdot}0$.

Mean of 17 spots between λ 260° and λ 140° (approximately)

$9^h\ 55^m\ 33^s{\cdot}9$.

Mean of 8 spots between λ 140° and λ 260°

$9^h\ 55^m\ 15^s{\cdot}3$.

Chart II.

N. TROPICAL SPOTS.

Lat. +11° to +18° Mean R = $9^h\ 55^m\ 28{\cdot}0^s$

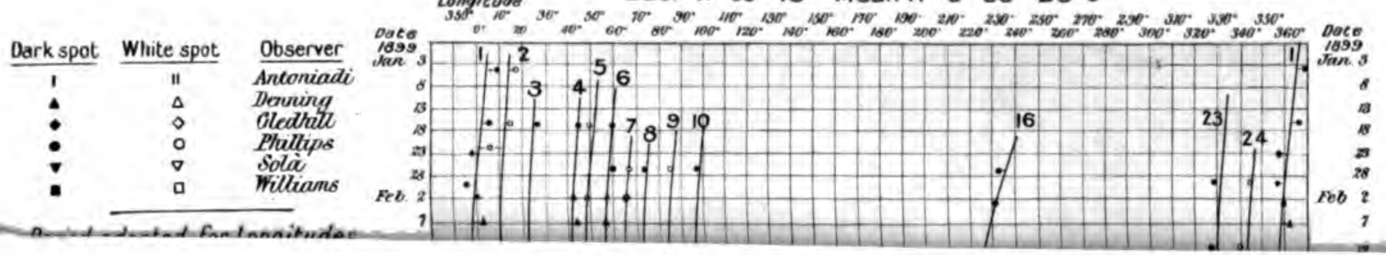


Table of Spots (*see* Chart II., Plate 6).

No.	Character of Spot.	Period of Observation. Days	No. of Observations.	Rotation Period. h m s	Remarks.
1	D	230	33	9 55 32·5	
2	W	204	25	9 55 35·7	Motion irregular. Spot intensely brilliant on June 11.
3	D	182	14	9 55 35·9	Spot rather small and faint.
4	D	63	5	9 55 35·8	Spot small and faint.
5	W	233	8	9 55 32·7	Spot faint and observations somewhat discordant.
6	D	146	20	9 55 33·7	Darkest marking on the planet, but died out in June. Quite detached from N.E.B. in good seeing. Probably identical with spot "A" of 1898.
7	W	187	27	9 55 33·4	
8	D	146	22	9 55 33·0	
9	W	216	41	9 55 32·5	Very bright and conspicuous.
10	D	216	27	9 55 32·7	Rather long spot. Detached from N.E.B.
11	W	128	12	9 55 31·4	Bright and rather large.
12	D	158	13	9 55 35·2	Long and dark.
13*a*	D	94	4	9 55 35·7	Really one spot, but sudden change of velocity near beginning of May.
13*b*	D	64	6	9 55 20·1	
14	W	71	7	9 55 18·2	Velocity checked on approaching λ 140°.
15	W	73	11	9 55 15·8	It is possible that this and spot 14 united at end of May to form one large spot.
16	D	138	28	9 55 14·2	Well-defined dark spot.
17	W	133	14	9 55 17·1	Velocity more rapid at first, but becoming slackened later.
18	D	75	7	9 55 8·5	Velocity most abnormal.
19	W	60	8	9 55 12·2	Moderately large and bright.
20	D	22	3	9 55 16·3	Period of observation very short, but identity certain, and velocity accords well with that of other spots.
21	D	150	12	9 55 36·5	Very long dark spot detached from N.E.B.
22	W	63	6	9 55 33·1	
23	D	139	12	9 55 34·5	Motion not uniform.
24	W	216	50	9 55 32·8	Remarkably brilliant and definite oval spot.

3. *The Red Spot.* Approx. lat. —21°.

This spot was again exceedingly faint and difficult, but, as was the case in 1898, with the exception of its S. edge, where it was in contact with the S.T.B., the complete oval outline could just be detected when the atmospheric conditions were favourable. To the writer the spot again appeared grey; but Mr. Williams speaks of it as exhibiting at times a feeble reddish or pinkish glow. At its *f* end the spot was fairly distinct, but the *p* end was almost of the last degree of faintness, and completely obliterated in imperfect seeing. It was, therefore, generally thought preferable to observe the central meridian transits of the well-known "hollow" or "bay" in the south equatorial belt, in which the red spot lies, rather than those of the spot itself. The former object was easily observed, even under the worst seeing conditions, and its rotation period may safely be regarded as identical with that of the spot.

With regard to the position of the spot there is some difference of opinion. The majority of observers appear to agree in placing it somewhat nearer the *f* end of the "hollow," and to the writer its central meridian passages seemed as much as three minutes later than those of the centre of the latter object. On the other hand, Mr. A. S. Williams states that he saw the spot of such a length that its centre was rather inclined to the *p* side of the "hollow."* His transits, which refer to the passages of the spot itself, are consequently considerably earlier than those of other observers.

Between the end of 1898 July and the close of the last apparition the "red-spot hollow" exhibited a striking irregularity of motion. On the planet's reappearance in the morning sky it was found from observations made in 1899 January that the hollow was about 3° or 4° ahead of its computed position according to its velocity of 1898. For the first few months of the apparition the increased velocity thus indicated was maintained, the rotation period at this time being not very much greater than that of the zero meridian of System II. (Mr. Crommelin's ephemeris). From 1898 August to 1899 April Mr. Denning found a mean period of $9^h\ 55^m\ 41^s{\cdot}2$; but, taking the apparition of 1899 separately and as a whole, the following value seems to satisfactorily represent the observations :—

$$R = 9^h\ 55^m\ 42^s{\cdot}0.$$

As the red spot is by far the most important and interesting feature on the surface of the Planet, the observations relating to this object are given, not in chart form, but in detail. The

* Mr. Williams wishes it to be understood that this statement refers to the centre of *figure* of the spot. He agrees with the other observers in putting the centre of *plainness* or *density* of the spot distinctly on the *f* side of the centre of the "hollow."

fourth column (O—C) contains the residuals or the differences between the observed positions and those calculated according to the adopted period of $9^h\ 55^m\ 42^s{\cdot}0$. The last column contains the initials of the observers, as follows:—

A = Antoniadi   P = Phillips
D = Denning   S = Solà
F = Flammarion   W = Williams
G = Gledhill

The residuals in the following table refer to transits of the "hollow," the observations of the spot itself being denoted by an asterisk. The transits of J. Comas Solà relate to the relatively dark *f* end of the spot.

Date. 1899.		Time of C. M. passage. h m	λ (System II.) °	O—C °	Observer.
Jan.	4	19 37	27·3	−0·7	P.
	4	19 40	29·1	*	P.
	16	19 36	29·4	+1·0	P.
	16	19 39	31·2	*	P.
Feb.	2	18 39	29·5	+0·5	D.
	7	17 46	29·0	−0·1	D.
	21	19 18	29·0	−0·6	P.
	21	19 20	30·2	*	P.
	24	16 49	30·0	+0·3	D.
	26	18 27	29·9	+0·1	D.
	26	18 28·5	30·8	+1·0	P.
	26	18 31·5	32·6	*	P.
Mar.	13	15 44	26·8	*	W.
	15	17 25	28·5	−1·8	P.
	20	16 34	29·7	−0·8	P.
	28	13 10	29·5	−1·3	P.
April	4	13 53·5	28·7	−2·3	P.
	12	10 36	32·3	+1·0	G.
	16	13 48	30·2	−1·2	P.
	16	13 52	32·6	+1·2	G.
	17	9 41	31·2	−0·2	G.
	19	11 15	29·0	−2·5	P.
	19	11 20	32·0	+0·5	D.
	21	12 53·5	29·2	−2·4	P.
	26	12 2·5	30·5	−1·2	P.
	26	12 3	30·8	−0·9	D.
	26	12 3	30·8	−0·9	G.
	30	...	47·1	*	S.
May	1	11 10	30·7	−1·2	P.
	3	12 44	28·3	*	W.

Date. 1899.		Time of C. M. passage. h m	λ (System II.) °	O−C °	Observer.
May	4	8 44	33·6	+1·6	G.
	6	10 15	29·3	*	W.
	6	10 17	30·5	−1·5	P.
	6	10 17	30·5	−1·5	MacEwen
	6	10 19	31·7	−0·3	D.
	6	10 20	32·3	+0·3	G.
	8	11 54·5	30·2	−1·9	P.
	8	11 57	31·7	−0·4	G.
	8	11 58	32·3	+0·2	D.
	11	9 24	30·4	−1·8	P.
	16	8 34	31·9	−0·5	G.
	18	10 14	33·0	+0·6	G.
	23	9 21	32·7	+0·1	P.
	25	11 0	33·1	+0·4	G.
	25	11 0·3	33·3	*	W.
	28	8 27	31·6	−1·2	P.
	28	8 30	33·4	+0·6	G.
	30	10 3	30·2	*	W.
	30	10 8	33·2	+0·4	G.
	30	10 9	33·8	+1·0	P.
	30	10 9·5	34·1	+1·3	A.
June	4	9 16	33·2	+0·2	P.
	4	9 17	33·8	+0·8	G.
	4	9 17·5	34·1	*	W.
	4	9 18	34·4	+1·4	D.
	4	9 18	34·4	+1·4	F.
	4	9 20·1	35·8	*	F.
	6	10 46·5	28·4	*	W.
	6	10 54·5	33·2	+0·1	P.
	6	10 56	34·1	+1·0	G.
	6	10 57	34·7	+1·6	D.
	6	...	46·5	*	S.
	9	8 25	33·8	+0·6	G.
	9	8 26	34·4	+1·2	D.
	9	...	52·0	*	S.
	11	9 58·2	30·5	*	W.
	11	10 2·5	33·1	−0·1	P.
	11	10 3	33·4	+0·2	G.
	11	10 4	34·0	+0·8	D.

Date. 1899.		Time of C. M. passage. h m	λ (System II.) °	O−C °	Observer.
June	14	7 32	32·9	−0·4	G.
	14	7 32	32·9	−0·4	D.
	16	9 8	31·4	*	W.
	16	9 12	33·8	+0·4	G.
	16	9 13	34·4	+1·0	D.
	16	9 14	35·0	+1·6	P.
	18	10 50·5	33·8	+0·3	P.
	21	8 20	33·5	−0·1	G.
	21	8 20	33·5	−0·1	D.
	23	9 58	33·1	−0·5	D.
	26	7 28	33·1	−0·6	G.
	26	7 29	33·7	0·0	D.
	28	9 8	33·9	+0·1	D.
July	5	9 56	34·1	+0·1	G.
	5	9 58	35·3	+1·3	D.
	5	...	45·3	*	S.
	8	7 27	34·6	+0·5	D.
	15	8 15	34·6	+0·2	G.
	17	9 56	36·0	+1·6	D.
	27	8 10	33·1	−1·7	G.
	27	8 11	33·7	−1·1	D.
	29	9 49	33·3	−1·5	D.
	30	5 47	37·0	+2·1	D.
Aug.	1	7 22	34·6	−0·3	P.
	1	7 22·5	34·9	0·0	D.
	6	6 29	33·1	−2·0	D.
	8	8 9	33·7	−1·5	D.
	8	8 11	34·9	−0·3	P.
	11	5 42	35·1	−0·2	D.
	13	7 22	35·7	+0·4	D.
	18	6 30	34·6	−0·9	D.
	23	5 44	37·0	+1·3	D.
	30	6 33	37·0	+1·1	D.
Sept.	6	7 21	36·4	+0·3	D.
	14	3 59	34·7	−1·7	D.
	16	5 41	36·5	0·0	D.

Note.—Mr. Denning secured a transit of the red-spot "hollow" on 1898 November 29 at 19^h 55^m (λ = 31°·9). This observation appears to be somewhat late, but it is valuable as indicating that the acceleration of velocity referred to above probably did not set in till late in the autumn.

4. *South Tropical Spots.* Approx. lat. $-18°$ to $-28°$

Mr. Williams has sent some valuable observations of white spots on the N. tropical zone, *i.e.* the bright zone between the S. edge of the south equatorial belt and the N. edge of the S.T.B. Four of these spots appear to give a mean value for this region of

$$9^{h}\ 55^{m}\ 20^{s}{\cdot}7.$$

The observations, however, are few in number, and might perhaps be identified differently. The above result, therefore, though probably correct, must necessarily be regarded as open to some degree of doubt. It is much to be regretted that no additional observations of these spots are available for discussion.

Table of Spots.

No.	Character of Spot.	Period of Observation. Days.	No. of Observations.	Rotation Period. h m s	Remarks.
1	W.	73	3	9 55 20·4	Very small and faint.
2	W.	24	3	9 55 26·8	Very small and faint.
3	W.	64	3	9 55 11·6	Very faint.
4	W.	60	3	9 55 23·8	Small and faint.

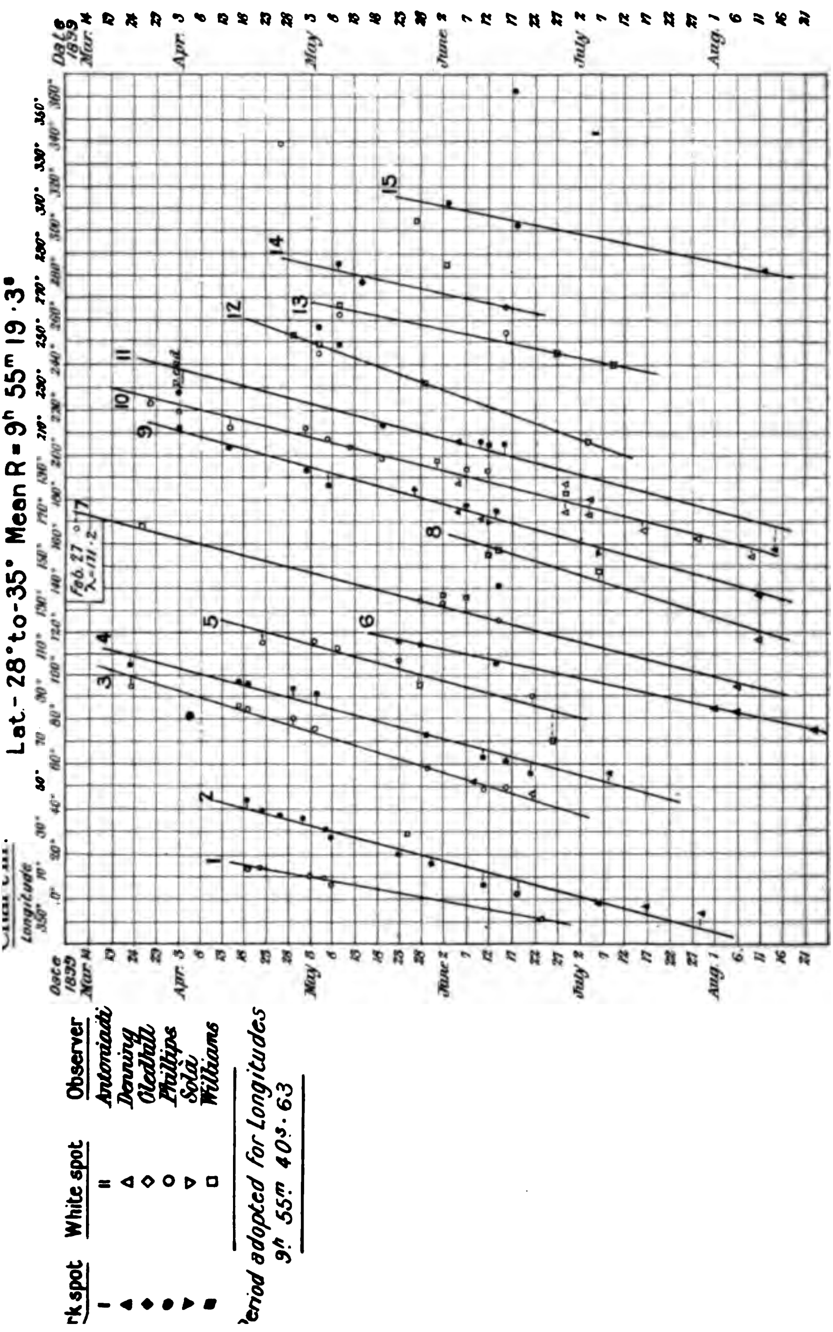
5. *South Temperate Spots.* Approx. lat. $-28°$ to $-35°$.

A considerable number of dark and white spots were visible on or at the S. edge of the S.T.B. during the apparition of 1899. In 1898 the period derived from six spots was $9^{h}\ 55^{m}\ 19^{s}{\cdot}4$ (*Monthly Notices*, 1898 December). In the present year fifteen spots give a mean of

$$9^{h}\ 55^{m}\ 19^{s}{\cdot}3.$$

As is the case with most of the Jovian currents, the spots in this latitude differed considerably amongst themselves, and the velocities of the individual spots varied from time to time. A glance at the chart, however, will show that there is no room for doubt as to the question of identification, and the mean result may be relied upon as being very near the truth.

Some of the white spots projected so far into the white S. temp. zone that they appear to have been largely influenced by the more rapidly drifting material of the great southern current. The periods of the dark spots on the S.T.B. in about latitude $-30°$ were far more uniform.


Lat. - 28° to -35° Mean R = 9h 55m 19·3s
Longitude
Date 1899
Mar.
Apr.
May
June
July
Aug.
Feb. 27
λ = 171·2
1
2
3
4
5
6
8
9
10
11
12
13
14
15
17
Dark spot
White spot
Observer
Antoniadi
Denning
Gledhill
Phillips
Solà
Williams
Period adopted for Longitudes
9h 55m 40s·63

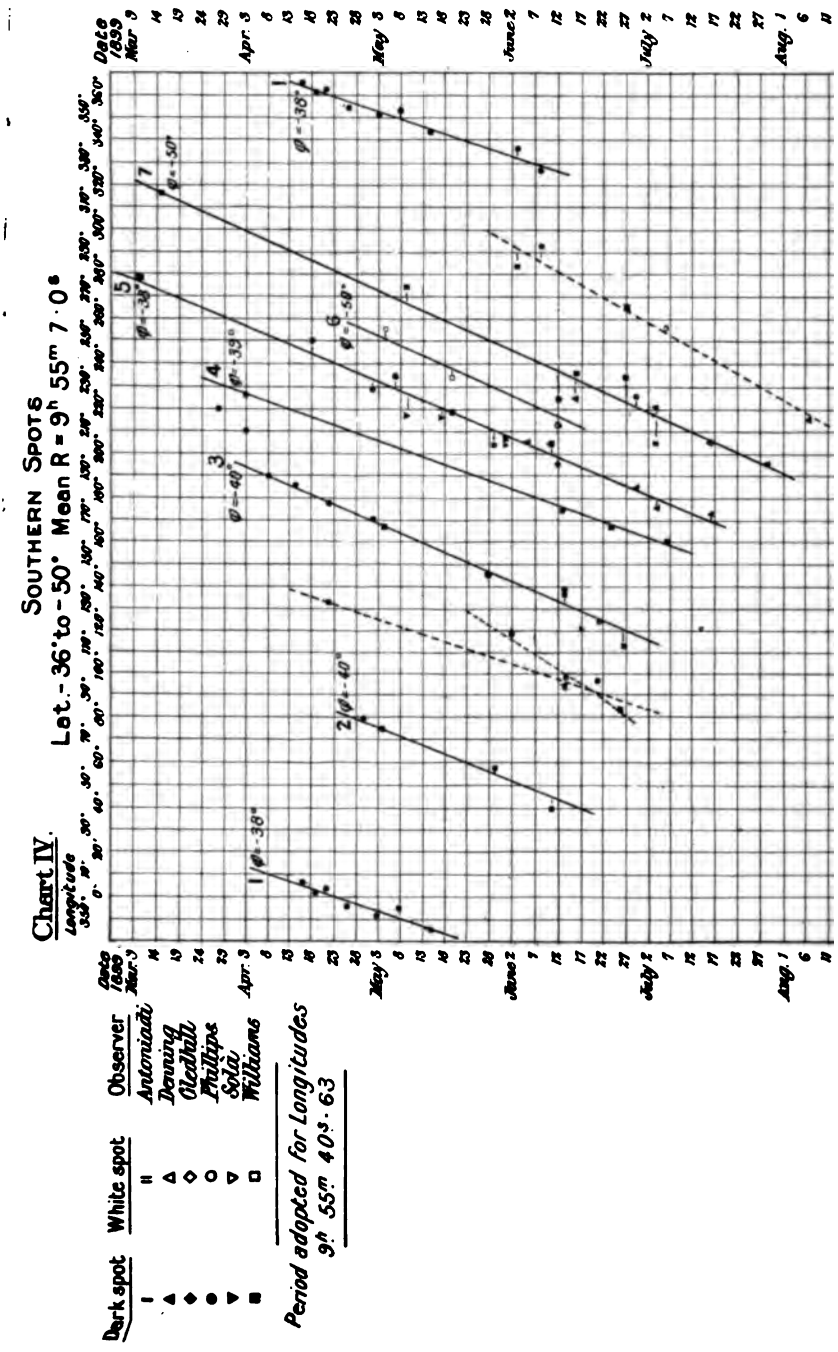


Chart IV.
SOUTHERN SPOTS
Lat. -36° to -50° Mean R = 9h 55m 7.0s
Longitude
Date 1899
Mar. 9
Apr. 3
May 3
June 2
July 2
Aug. 1
Dark spot
White spot
Observer
Antoniadi
Denning
Oldhill
Phillips
Sola
Williams
Period adopted for Longitudes 9h 55m 40s.63

[redacted]

Table of Spots (*see* Chart III., Plate 7).

No.	Character of Spot.	Period of Observation. Days.	No. of Observations.	Rotation Period. h	m	s	Remarks.
1	W	65	6	9	55	24·4	
2	D	101	13	9	55	19·2	Rotation much more rapid till latter part of June, then suddenly slackened.
3	W	90	10	9	55	16·6	
4	D	107	10	9	55	19·0	Rather dark. Motion varied considerably.
5	W	65	7	9	55	17·5	Velocity varied considerably.
6	D	92	6	9	55	22·3	Observations remarkably accordant.
7	W	160	8	9	55	18·7	
8	W	60	4	9	55	13·8	
9	D	130	13	9	55	18·2	
10	W	140	19	9	55	19·7	Bright spot.
11	D	133	7	9	55	18·9	
12	W	65	5	9	55	11·7	
13	W	60	5	9	55	24·8	
14	D	35	3	9	55	20·5	
15	D	70	3	9	55	24·0	

6. *The Great Southern Current.* Approx. lat. $-36°$ to $-50°$.

This current was very well observed in 1899, the mean result being in close agreement with that of 1898. As is only to be expected, the observations, relating as they do to more or less faint markings in high latitudes, show some discordances ; but, on the whole, the agreement is very satisfactory and the indentifications beyond doubt.

The mean rotation period derived from the observations of seven spots works out as

$$9^h\ 55^m\ 7^s{\cdot}0,$$

which is just $0^s{\cdot}7$ greater than that derived from two spots in 1898.

Table of Spots (*see* Chart IV., Plate 8).

No.	Character of Spot.	Period of Observation.	No. of Observations.	Rotation Period. h	m	s	Remarks.
1	D	53	9	9	55	13·4	Dark spot at *p* end of dusky streak.
2	D	43	4	9	55	7·3	Following end of dark streak.
3	D	79	10	9	55	4·4	
4	D	94	4	9	55	11·7	Observations scanty, but no doubt as to identity.
5	D	128	17	9	55	6·2	
6	W	38	3	9	55	3·2	At mouth of rift in N. polar shading.
7	D	135	11	9	55	3·1	Observations rather discordant.

Note.—The approximate latitude (ϕ) of the spots is given on the chart.

Summary of Results.

	Current	Approx. Lat.	No of Spots.	Rotation Period. h	m	s
1	Northern spots	From $+24°$ to $+33°$	1	9	55	32·0
			3	9	55	56·9
2	N. trop. spots	From $+11°$ to $+18°$	25	9	55	28·0
			(17	9	55	33·9)
			(8	9	55	15·3)
3	"Red spot"	$-21°$	1	9	55	42·0
4	S. trop. spots	From $-18°$ to $-28°$	4	9	55	20·7 *
5	S. temp. spots	From $-28°$ to $-35°$	15	9	55	19·3
6	Southern spots	From $-36°$ to $-50°$	7	9	55	7·0

* This result must be regarded as somewhat doubtful.

Observations of the Lunar Eclipse, 1899 *December* 16, *at the Liverpool Observatory.* By W. E. Plummer.

The weather conditions at the time of the lunar eclipse were not very favourable for the observation of occultations. During the early part of the eclipse the sky was quite cloudy, the Moon being only occasionally visible through short breaks.

The following observations were made with the 8-inch equatorial and a power of 80. The times noted were thought to be generally satisfactory, but the identification of the stars is by no means certain.

Star.	Phase.	Greenwich Mean Time. h	m	s
B. D. 22° No. 1003	Disapp.	12	57	59·9
„ 22 „ 1004	„	13	7	5·7
„ 22 „ 1006	„	13	14	53·2
„ 22 „ 1011	„	13	20	24·8
„ 22 „ 993	Reapp.	13	28	47·9
„ 22 „ 1006	„	13	48	43·4

The occultation of *Neptune* was looked for, but the planet was lost in the glare of the Moon as it approached the limb.

An attempt was made near the time of maximum eclipse to determine the angular breadth of the unobscured portion, but the observation proved impossible. The attempt seemed to indicate that the portion in the penumbra was greater than was predicted, but the uncertainty of the effects of irradiation and the difficulty of deciding on the termination of the shadow rendered any definite conclusion impossible.

Liverpool Observatory,
1900 *Jan.* 11.

Note on the Variable Star η Argûs. By Col. E. E. Markwick.

As the recorded observations of the magnitude of this historic variable star appear to have been but few and far between in past time, and as I made a pretty careful determination of it in the years 1883 and 1884, I think it worth while to record it.

The observations were made at Pietermaritzburg, Natal, with a $2\frac{3}{4}$-inch refractor, eyepiece, power about 28.

1883	Dec. 28	7·5	Two or three steps < D; about = B.
1884	Feb. 5	7·54	Between B and D in brightness.
	Feb. 18	7·6	While observing, a cloud came over, dimming η and the surrounding stars. I thus had a good opportunity of noting the different times of disappearance of the stars. After careful observation I came to the conclusion that it was about = D in brightness.
	June 19	7·46	Between stars A and B in brightness.
	20	7·46	As before.

The comparison stars used were :

	m.	
A = B 3202	7·44	As at p. 256, *Uran. Arg.*
B = B 3204	7·48	
D = G 1332	7·60	

There was little or no variation apparently while the star was under observation, so I think the net result of the above may be taken as

1884·23 7·51

My glass was then only provided with a very rough equatorial stand without circles, but I made certain of the identification of η on 1883 June 20 when I compared its position with that of star D. Using an eyepiece with three threads, one parallel to a circle of declination, and two each inclined 45° to the former, the telescope was adjusted so that D ran along the central thread. Then the times of D passing the centre and of *η Argûs* passing the two threads were noted eight times. A mean of these was taken, and with the corresponding differences in R.A. and Dec. the position of η was ascertained, that of D being taken from the *U. Arg.* The resulting position ($10^h\ 40^m\ 14^s$ R.A. 59° 1′·6 S. Dec.) was such as to ensure and fix at once the correct identification of η, differing as it did from the catalogue position by 1^s only in R.A. and 0′·1 in Dec. This procedure was very necessary, as the variable is surrounded by numbers of stars of about the same degree of brightness, from which by its appearance alone I found it at first impossible to distinguish it.

Moreover, to add to possible confusion, the circle indicating variability is placed round the wrong star in the U.A. Map, viz. No. 227 (U.A.) *Carinæ*, a star a little to the S. of the true variable. This error is, however, duly noted in the body of the work.

Combining my result with the data in Mr. Innes's Paper (*Monthly Notices*, vol. lix. p. 570) we get the following :—

1884·23	7·51
1886·2	7·60
1896·4	7·58
1897·2	7·60
1899·5	7·71

It would hence appear that this star, which once (1843) exceeded every star but *Sirius* in brightness, has, for the sixteen years 1883–1889 remained at or about $7^{m}\cdot6$ with a possible slight tendency to diminish in magnitude.

Observations of Meteors at the Royal Alfred Observatory, Mauritius, 1899 *November.*

(*Communicated by T. F. Claxton.*)

The Leonid display witnessed at Mauritius was but meagre, though the results may be of some value as indicating what occurred at this station, whose latitude is 20° 5′ 39″ S., and longitude $3^{h}\ 50^{m}\ 12^{s}\cdot6$ E.

Watch was kept by three observers on the mornings of November 14 and 15 (from midnight to sunrise), and on the 16th one observer watched at intervals, but saw no meteors.

It is probable that the maximum occurred after sunrise.

On November 14 the Moon set at 2.20 A.M., and at 3.5 A.M. on the 15th.

Until 2 A.M. on the 14th the sky in the neighbourhood of the radiant was occasionally covered with very thin misty clouds through which bright stars only were faintly visible, otherwise the weather on each night was fine and clear.

The zodiacal light was observed on the 14th and 15th. The axis of the cone at 2.30 on each morning appeared to extend from *α Leonis* along a parallel of declination to the horizon, the apex gradually receding from that star as the morning advanced, or, in other words, keeping at an approximately constant altitude. The base stretched for about 20° along the horizon. No pink tinge was distinguishable.

(Mauritius Civil Time). d.	h.	m.	s.	Apparent Size. m	Duration in Secs. s	Colour.	Train.	From R.A. °	From Dec. °	To R.A. °	To Dec. °	Observer.
14	2	41	14	3	1	Yellow	None	120	+30	137	+28	C.
	2	59	32	2	1	„	Slight	128	+22	145	+21	C.
	3	8	35	3	1	Bluish white	Broken, 3 secs.	124	+40	120	+44	O.
	3	10	24	3	½	„	None	147	+13	160	+15	O.
	3	14	54	3	½	„	„	117	+42	107	+58	C.
	3	23	53	4	1	„	Slight	148	+23	147	+32	C.
	3	25	0	3	1	„	„	115	+18	132	+15	O.
	3	30	22	3	½	Yellow	„	162	+25	175	+30	C.
d.	h.	m.	s.					°	°	°	°	
15	0	26	56	>1	2	Bluish	Red	104	+39	118	+51	C.
	0	48	9	>1	3	Bluish white	Slight	123	+40	134	+39	O.
	1	28	51	>1	2½	„	„	113	+ 5	144	+ 3	O.
	2	28	18	2	½	„	„	128	+ 4	135	+11	C.
		32	28	2	½	Bluish	Slight, ½ sec.	142	+11	149	+ 7	W.
		33	14	1	½	Bluish white	None	71	+32	68	+43	C.
		45	26	3	½	Yellow	Slight	150	−11	157	−33	C. & O.
		54	31	2	1	Bluish white	Broken, 1 sec.	120	+27	103	+32	C. & W.
	3	7	31	2	2	„	Slight	163	−17	173	−17	C. & O.
		12	37	2	1	Bluish	„	150	−16	148	−31	W.
		13	38	1	1	Bluish white	„	166	+22	175	+21	C.
		19	48	3	½	„	„	162	−17	173	−17	C.
		25	54	1	½	„	„	170	− 2	182	− 8	O.
		25	59	2	1	„	„	166	−22	166	−30	O.
		30	23	3	½	Bluish	„	152	− 9	165	−24	W.
		32	33	3	1	Bluish white	„	175	−17	186	−26	C.
		34	42	2	1	„	„	180	−16	186	−24	W.
		35	47	2	1	„	„	133	+47	120	+58	C.
		36	22	2	1	Bluish	„	133	+47	120	+58	O.
		43	40	1	1	„	Brilliant	167	−50	172	−61	W.
		49	20	3	½	Bluish white	None	150	+18	166	+21	C.
		49	30	3	1	„	Train	150	+ 2	150	−11	W.
		52	1	2	½	„	Train, 1 sec.	160	+11	170	+ 4	C.
		55	6	1	1	Bluish	Slight	150	+10	175	+15	O.
		55	58	1	½	„	Brilliant	185	−15	188	−19	W.
		59	16	2	½	Bluish white	Bright	160	+ 9	170	− 2	C.
	4	0	46	2	½	„	Slight	166	+19	178	+15	W.
		9	35	2	1½	„	None	170	− 2	182	− 8	C.
		9	43	1	1	„	Brilliant	150	−45	143	−61	W.
		10	44	1	1½	Bluish	Train, ½ sec.	170	− 2	182	− 8	O.
		13	30	1	½	Bluish white	Fine	151	−12	126	−23	C.

The initials C., W., O. are those of Mr. Claxton, Mr. Walter, and Olivier respectively.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites made at the Royal Observatory, Greenwich, in the Year 1899.

Communicated by the Astronomer-Royal.

Day. 1899.		Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Jan.	19	Disapp. μ Arietis	Old Altazimuth	100	Dark	8 4 21·29	P. M.
Feb.	22	Disapp. Piazzi VIII. 106	Sheepshanks Equat.	100	„	12 41 44·13	H.
	22	„ „	Astrographic Equat.	120	„	12 41 43·61	R. O.
	22 (a)	Reapp. „	Sheepshanks Equat.	100	Bright	13 50 38·91	H.
April	17	Disapp. 3 Cancri	„ „	100	Dark	10 44 47·71	R.
May	26 (a)	Reapp. 7 Sagittarii	„ „	55	„	12 38 53·37	W. B.
	26	„ 9 Sagittarii	„ „	55	„	13 15 24·89	W. B.
July	19	„ Bradley 2153	„ „	55	Bright	9 17 16·81	W. S.
	19	„ 26 Ophiuchi	„ „	55	„	9 24 38·11	W. S.
Dec.	16	Disapp. B. D. 22° 991	28-inch Equat.	200	Eclipsed	12 16 8·46	W. B.
	16	„ Lal. 10708-9	Merz 13-inch Equat.	265	„	12 17 2·66	D.
	16 (b)	„ „	Astrographic Equat.	225	„	12 17 2·50	H.
	16	„ „	28-inch Equat.	200	„	12 17 3·13	W. B.
	16	„ „	Sheepshanks Equat.	150	„	12 17 2·81	W. L.

Day.	Phenomenon.		Telescope.	Power.	Moon's Limb	Mean Solar Time of Observation.	Observer.
1899.						h m s	
Dec. 16	Disapp.	Piazzi V. 184	Merz 13-inch Equat.	265	Eclipsed	12 22 55·38	D.
16 (*b*)	„	„	Astrographic Equat.	225	„	12 22 55·42	H.
16	„	„	28-inch Equat.	200	„	12 22 56·15	W. B.
16	„	„	Sheepshanks Equat.	150	„	12 22 55·94	W.
16	„	B. D. 22° 999	Merz. 13-inch Equat.	265	„	12 25 5·82	D.
16 (*b*)	„	„	Astrographic Equat.	225	„	12 25 6·37	H.
16	„	„	28-inch Equat.	200	„	12 25 6·71	W. B.
16 (*c*)	„	„	Sheepshanks Equat.	150	„	(12 25 9·09)	W.
16 (*c*)	„	B. D. 22° 998	28-inch Equat.	200	„	12 27 44·18	W. B.
16 (*d*)	„	B. D. 22° 1000	Merz 13-inch Equat.	265	„	12 37 1·96	D.
16	„	„	Astrographic Equat.	225	„	12 37 1·53	H.
16	„	„	28-inch Equat.	200	„	12 37 1·85	W. B.
16	„	„	Sheepshanks Equat.	150	„	12 37 1·95	W.
16	„	Anonymous *b*	28-inch Equat.	200	„	12 41 39·29	W. B.
16 (*c*)	„	Lal. 10739–40	Merz 13-inch Equat.	265	„	12 54 38·95	D.
16	„	„	Astrographic Equat.	225	„	12 54 38·15	H.
16	„	„	28-inch Equat.	200	„	12 54 39·06	W. B.
16	„	„	Sheepshanks Equat.	150	„	12 54 39·38	W.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1899. Dec. 16	Disapp. Lal. 10739–40	Corbett Tel.	100	Eclipsed	12 54 39·16	P. M.
16	„ Lal. 10741–2	Merz 13-inch Equat.	265	„	13 0 53·83	D.
16	„ „	Astrographic Equat.	225	„	13 0 54·04	H.
16	„ „	28-inch Equat.	200	„	13 0 53·94	W. B.
16	„ „	Sheepshanks Equat.	150	„	13 0 53·57	W.
16	„ „	Corbett Tel.	100	„	13 0 53·84	P. M.
16	„ Anonymous *c*	28-inch Equat.	200	„	13 3 53·35	W. B.
16	„ Anonymous *d*	„ „	200	„	13 5 35·67	W. B.
16	„ Anonymous *e*	„ „	200	„	13 6 37·01	W. B.
16	„ Anonymous *f*	„ „	200	„	13 8 19·13	W. B.
16	„ Lal. 10745	Merz. 13-inch Equat.	265	„	13 9 4·19	D.
16 (*b*)	„ „	Astrographic Equat.	225	„	13 9 4·12	H.
16	„ „	28-inch Equat.	200	„	13 9 4·61	W. B.
16	„ „	Sheepshanks Equat.	150	„	13 9 4·66	W.
16	„ Anonymous *g*	28-inch Equat.	200	„	13 14 3·58	W. B.
16	Reapp. B. D. 22° 991	Merz 13-inch Equat.	265	„	13 20 34·89	D.
16 (*c*)	„ „	Astrographic Equat.	225	„	13 20 34·73	H.
16	„ „	28-inch Equat.	200	„	13 20 35·21	W. B.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1899.					h m s	
Dec. 16 (*a*)	Reapp. B. D. 22° 991	Sheepshanks Equat.	150	Eclipsed	(13 20 51·08)	W.
16	Disapp. B. D. 22° 1009	Merz. 13-inch Equat.	265	,,	13 28 20·60	D.
16 (*a*)	,, ,,	Astrographic Equat.	225	,,	13 28 19·66	H.
16	,, ,,	28-inch Equat.	200	,,	13 28 19·44	W. B.
16 (*c*)	,, ,,	Sheepshanks Equat.	150	,,	(13 28 24·81)	W.
16	Reapp. Piazzi V. 184	Merz 13-inch Equat.	265	,,	13 31 2·16	D.
16 (*e*)	,, ,,	Astrographic Equat.	225	,,	13 31 2·22	H.
16	,, ,,	28-inch Equat.	200	,,	13 31 2·50	W. B.
16	,, ,,	Sheepshanks Equat.	150	,,	13 31 1·77	W.
16	,, Lal. 10708–9	Merz 13-inch Equat.	265	,,	13 35 25·45	D.
16 (*e*)	,, ,,	Astrographic Equat.	225	,,	13 35 25·92	H.
16	,, ,,	28-inch Equat.	200	,,	13 35 26·19	W. B.
16	,, ,,	Sheepshanks Equat.	150	,,	13 35 26·07	W.
16	,, B. D. 22° 1010	Merz 13-inch Equat.	265	,,	13 39 58·70	D.
16	,, ,,	Astrographic Equat.	225	,,	13 40 0·57	H.
16	,, ,,	28-inch Equat.	200	,,	13 39 59·44	W. B.
16	,, ,,	Sheepshanks Equat.	150	,,	(13 40 3·43)	W.
16	,, B. D. 22° 999	Merz 13 inch Equat.	265	,,	13 40 24·53	D.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1899.					h m s	
Dec. 16	Reapp. B. D. 22° 999	28-inch Equat.	200	Eclipsed	13 40 25·27	W. B.
16	Disapp. B. D. 22° 1014	Merz 13-inch Equat.	265	„	13 49 46·58	D.
16	„ „	28-inch Equat.	200	„	13 49 46·33	W. B.
16	„ Anonymous *h*	„ „	200	„	13 54 3·73	W. B.
16	„ Anonymous *j*	„ „	200	„	13 55 55·43	W. B.
16	Reapp. Lal. 10745	Merz 13-inch Equat.	265	„	13 57 36·80	D.
16	„ „	Astrographic Equat.	225	„	13 57 33·80	H.
16	„ „	Sheepshanks Equat.	150	„	13 57 36·27	W.
16	„ Lal. 10741–2	Merz 13-inch Equat.	265	„	13 58 22·48	D.
16	„ „	Astrographic Equat.	225	„	13 58 21·58	H.
16	„ B. D. 22° 1003	Merz 13-inch Equat.	265	„	(14 10 40·66)	D.
16 (*a*)	„ „	Astrographic Equat.	225	„	14 10 34·09	H.
16	„ „	28-inch Equat.	200	„	14 10 34·43	W. B.
16	„ „	Sheepshanks Equat.	150	„	14 10 32·56	W.
16	„ B. D. 22° 1009	28-inch Equat.	200	„	14 31 0·68	W. B.

Notes.

(*a*) Not considered a good observation. (*b*) Star apparently projected on limb before disappearance.
(*c*) Star very faint. (*d*) Star appeared to take 0·2^s to disappear. (*e*) Sudden.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
1899.					h m s	h m	
April 18	III. (a)	Occ. R. Last contact	Sheepshanks Equat.	120	10 51 4·91	10 41	B.
May 6	II.	Tr. Ing. First contact	"	"	9 40 3·99		H.
6	II.	Bisection	"	"	9 42 48·55	9 42	"
6	II.	Last contact	"	"	9 45 23·13		"
6	I.	Occ. D. First contact	"	"	11 53 57·17		"
6	I.	Bisection	"	"	11 56 11·80	11 56	"
6	I.	Last seen	"	"	11 58 21·45		"
6	II.	Tr. Egr. First contact	"	"	11 55 11·97		"
6	II.	Bisection	"	"	11 56 56·68	11 56	"
6	II.	Last contact	"	"	12 0 41·06		"

Note.

(a) The satellite emerged very slowly.

The observations of occultations of stars on December 16 were made during a partial eclipse of the Moon.

The initials D., H., B., W. B., R., H. F., R. C., W., P. M., W. S., are those of Mr. Dyson, Mr. Hollis, Mr. Bryant, Mr. Bowyer, Mr. Rendell, Mr. Furner, Mr. Cheeseman, Mr. Witchell, Mr. Melotte, and Mr. Stevens respectively.

Royal Observatory, Greenwich,
1900 *January* 12.

Ephemeris for Physical Observations

Greenwich Noon.	P.	L—O.	B.	A—L.	*B.*	Q.	R.
1900.	°	°	°	°	°	°	°
Aug. 24	338·43	193·51	+ 7·32	−28·06	−6·74	274·46	31·31
26	339·15	194·69	7·85	28·27	6·31	275·03	31·55
28	339·87	195·87	8·37	28·50	5·88	275·59	31·79
30	340·60	197·05	8·89	28·74	5·45	276·14	32·02
Sept. 1	341·33	198·23	9·40	28·96	5·02	276·68	32·25
3	342·06	199·40	+ 9·91	−29·19	−4·58	277·21	32·48
5	342·80	200·57	10·40	29·43	4·15	277·73	32·70
7	343·54	201·74	10·89	29·65	3·72	278·25	32·92
9	344·29	202·91	11·37	29·90	3·28	278·76	33·14
11	345·04	204·08	11·84	30·15	2·85	279·26	33·36
13	345·79	205·25	+12·30	−30·40	−2·42	279·75	33·57
15	346·54	206·41	12·76	30·64	1·99	280·24	33·78
17	347·29	207·57	13·21	30·89	1·56	280·72	33·99
19	348·04	208·73	13·65	31·14	1·14	281·19	34·20
21	348·79	209·89	14·08	31·39	0·71	281·65	34·40
23	349·55	211·05	+14·50	−31·65	−0·28	282·10	34·60
25	350·30	212·20	14·92	31·89	+0·14	282·55	34·80
27	351·05	213·35	15·33	32·15	0·56	282·98	34·99
29	351·80	214·50	15·73	32·41	0·98	283·40	35·18
Oct. 1	352·55	215·65	16·11	32·66	1·40	283·81	35·36
3	353·29	216·80	+16·48	−32·92	+1·82	284·21	35·54
5	354·03	217·94	16·85	33·17	2·24	284·59	35·71
7	354·77	219·08	17·21	33·43	2·65	284·97	35·87
9	355·51	220·22	17·55	33·68	3·07	285·34	36·03
11	356·24	221·35	17·89	33·92	3·48	285·70	36·18
13	356·97	222·48	+18·22	−34·17	+3·89	286·05	36·33
15	357·69	223·60	18·54	34·41	4·30	286·38	36·48
17	358·41	224·71	18·84	34·65	4·70	286·70	36·62
19	359·13	225·81	19·13	34·87	5·10	287·02	36·75
21	359·84	226·91	19·42	35·10	5·50	287·33	36·87
23	0·55	228·01	+19·69	−35·33	+5·90	287·62	36·99
25	1·24	229·10	19·96	35·55	6·30	287·90	37·10
27	1·92	230·19	20·22	35·76	6·69	288·17	37·20
29	2·60	231·27	20·46	35·97	7·08	288·43	37·29
31	3·27	232·34	+20·69	−36·17	+7·47	288·68	37·37

of Mars, 1900–01. By A. C. D. Crommelin.

Greenwich Noon.	⊙	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω₀	Passage of Zero Meridian.	
1900.	°	m	"	"	°	h m	h m
Aug. 24	344·00	16·042	4·98	0·36	336·80	1 35·41	2 15·22
26		15·956	5·00	0·37	317·42	2 55·03	3 34·84
28		15·868	5·03	0·37	298·05	4 14·65	4 54·46
30		15·779	5·06	0·38	278·68	5 34·27	6 14·08
Sept. 1	348·17	15·689	5·09	0·39	259·31	6 53·89	7 33·70
3		15·597	5·12	0·40	239·94	8 13·51	8 53·32
5		15·503	5·15	0·41	220·57	9 33·12	10 12·92
7		15·408	5·18	0·42	201·21	10 52·71	11 32·50
9	352·28	15·311	5·21	0·43	181·85	12 12·29	12 52·08
11		15·213	5·25	0·44	162·49	13 31·87	14 11·66
13		15·113	5·28	0·45	143·13	14 51·44	15 31·23
15		15·012	5·32	0·46	123·77	16 11·01	16 50·79
17	356·33	14·909	5·35	0·46	104·42	17 30·56	18 10·33
19		14·806	5·39	0·47	85·07	18 50·10	19 29·86
21		14·699	5·43	0·48	65·72	20 9·61	20 49·36
23		14·590	5·47	0·49	46·37	21 29·11	22 8·86
25	0·34	14·480	5·51	0·50	27·03	22 48·61	23 28·36
27		14·368	5·56	0·51	7·69	...	0 8·10
29		14·255	5·60	0·51	348·35	0 47·85	1 27·61
Oct. 1		14·141	5·65	0·52	329·01	2 7·35	2 47·10
3	4·29	14·025	5·69	0·53	309·68	3 26·83	4 6·57
5		13·908	5·74	0·54	290·35	4 46·29	5 26·02
7		13·789	5·79	0·55	271·02	6 5·73	6 45·44
9		13·668	5·84	0·56	251·70	7 25·14	8 4·84
11	8·20	13·546	5·89	0·57	232·38	8 44·54	9 24·23
13		13·423	5·95	0·58	213·07	10 3·92	10 43·59
15		13·298	6·00	0·59	193·76	11 23·27	12 2·94
17		13·172	6·06	0·59	174·46	12 42·60	13 22·26
19	12·c6	13·045	6·12	0·60	155·16	14 1·92	14 41·56
21		12·915	6·18	0·61	135·87	15 21·20	16 0·82
23		12·784	6·24	0·62	116·59	16 40·44	17 20·04
25		12·652	6·31	0·63	97·32	17 59·64	18 39·22
27	15·88	12·519	6·38	0·64	78·06	19 18·78	19 58·35
29		12·384	6·45	0·65	58·80	20 37·91	21 17·46
31		12·248	6·52	0·66	39·55	21 57·01	22 36·55

Greenwich Noon.		P.	L–O.	B.	A–L.	*B*.	Q.	E.
1900. Nov.	2	3°93	233°40	+20°91	−36°36	+ 7°85	288°91	37°43
	4	4·58	234·45	21·13	36·54	8·23	289·13	37·49
	6	5·23	235·49	21·33	36·71	8·61	289·35	37·54
	8	5·87	236·51	21·51	36·86	8·99	289·56	37·58
	10	6·51	237·52	21·68	37·00	9·36	289·76	37·61
	12	7·14	238·52	+21·85	−37·14	+ 9·73	289·94	37·62
	14	7·71	239·51	22·01	37·26	10·10	290·11	37·63
	16	8·30	240·49	22·15	37·37	10·47	290·27	37·61
	18	8·88	241·44	22·29	37·46	10·83	290·42	37·58
	20	9·45	242·38	22·42	37·53	11·19	290·56	37·53
	22	10·01	243·31	+22·53	−37·59	+11·54	290·69	37·47
	24	10·55	244·23	22·64	37·64	11·89	290·80	37·41
	26	11·08	245·12	22·74	37·67	12·24	290·90	37·32
	28	11·59	245·99	22·82	37·67	12·58	290·99	37·21
	30	12·10	246·84	22·89	37·66	12·92	291·08	37·08
Dec.	2	12·58	247·68	+22·96	−37·63	+13·26	291·15	36·93
	4	13·04	248·50	23·02	37·57	13·60	291·21	36·76
	6	13·49	249·28	23·08	37·48	13·93	291·26	36·56
	8	13·92	250·03	23·12	37·36	14·25	291·30	36·35
	10	14·34	250·75	23·15	37·21	14·57	291·33	36·13
	12	14·74	251·44	+23·18	−37·02	+14·89	291·35	35·88
	14	15·12	252·10	23·20	36·81	15·21	291·36	35·58
	16	15·48	252·73	23·22	36·56	15·52	291·35	35·25
	18	15·82	253·33	23·23	36·29	15·83	291·33	34·89
	20	16·14	253·89	23·23	35·98	16·13	291·30	34·50
	22	16·44	254·42	+23·22	−35·63	+16·43	291·26	34·09
	24	16·71	254·91	23·20	35·24	16·72	291·20	33·64
	26	16·96	255·36	23·17	34·80	17·01	291·13	33·17
	28	17·18	255·78	23·14	34·34	17·30	291·05	32·65
	30	17·38	256·15	23·10	33·82	17·58	290·96	32·10
1901 Jan.	1	17·56	256·47	+23·06	−33·26	+17·86	290·86	31·50
	3	17·72	256·74	23·02	32·64	18·14	290·74	30·88
	5	17·86	256·98	22·98	31·99	18·41	290·59	30·21
	7	17·96	257·16	22·93	31·27	18·67	290·41	29·49
	9	18·02	257·29	22·87	30·51	18·93	290·20	28·73
	11	18·06	257·36	+22·80	−29·69	+19·19	289·95	27·92
	13	18·09	257·38	+22·73	−28·80	+19·44	289·67	27·06

Greenwich Noon.	⊙	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.	
1900.	°	m	"	"	°	h m	h m
Nov. 2		12·111	6·59	0·67	20·31	23 16·08	23 55·60
4	19·65	11·973	6·67	0·68	1·07	...	0 35·11
6		11·835	6·74	0·69	341·85	1 14·59	1 54·06
8		11·695	6·82	0·70	322·64	2 33·52	3 12·96
10		11·555	6·91	0·71	303·44	3 52·40	4 31·81
12	23·40	11·413	6·99	0·72	284·26	5 11·22	5 50·61
14		11·270	7·08	0·73	265·09	6 29·99	7 9·36
16		11·126	7·17	0·74	245·94	7 48·70	8 28·03
18		10·982	7·27	0·74	226·80	9 7·35	9 46·65
20	27·10	10·837	7·37	0·75	207·68	10 25·93	11 5·19
22		10·691	7·47	0·75	188·57	11 44·43	12 23·64
24		10·544	7·57	0·76	169·48	13 2·83	13 42·00
26		10·397	7·68	0·76	150·41	14 21·16	15 0·32
28	30·77	10·249	7·79	0·77	131·36	15 39·45	16 18·56
30		10·101	7·90	0·77	112·33	16 57·63	17 36·68
Dec. 2		9·954	8·02	0·78	93·31	18 15·70	18 54·69
4		9·806	8·14	0·78	74·31	19 33·65	20 12·58
6	34·42	9·658	8·26	0·79	55·35	20 51·50	21 30·33
8		9·510	8·39	0·79	36·43	22 9·14	22 47·93
10		9·362	8·52	0·80	17·53	23 26·70	...
12		9·214	8·66	0·80	358·65	0 5·45	0 44·18
14	38·03	9·067	8·80	0·81	339·80	1 22·89	2 1·56
16		8·921	8·95	0·81	321·00	2 40·18	3 18·73
18		8·776	9·10	0·81	302·23	3 57·24	4 35·73
20		8·631	9·25	0·80	283·49	5 14·18	5 52·61
22	41·62	8·487	9·41	0·80	264·78	6 31·00	7 9·36
24		8·343	9·57	0·79	246·10	7 47·68	8 25·97
26		8·200	9·73	0·79	227·47	9 4·17	9 42·33
28		8·059	9·90	0·78	208·89	10 20·44	10 58·52
30	45·19	7·920	10·08	0·78	190·34	11 36·55	12 14·55
1901 Jan. 1		7·784	10·25	0·78	171·82	12 52·50	13 30·42
3		7·650	10·43	0·77	153·35	14 8·29	14 46·13
5		7·517	10·62	0·75	134·93	15 23·88	16 1·54
7	48·74	7·388	10·81	0·73	116·57	16 39·15	17 16·71
9		7·260	10·99	0·71	98·26	17 54·22	18 31·68
11		7·134	11·19	0·68	80·00	19 9·09	19 46·45
13		7·012	11·38	0·65	61·78	20 23·76	21 1·02

Greenwich Noon.		P.	L−O.	B.	A−L.	β.	Q.	E.
1901.								
Jan.	15	18°·09	257°·37	+22°·66	−27°·89	+19°·69	289°·35	26°·15
	17	18·04	257·29	22·58	26·91	19·93	289·00	25·19
	19	17·97	257·14	22·51	25·86	20·17	288·62	24·18
	21	17·86	256·94	22·43	24·76	20·40	288·20	23·12
	23	17·73	256·69	22·35	23·60	20·62	287·75	22·01
	25	17·57	256·39	+22·27	−22·40	+20·84	287·25	20·84
	27	17·38	256·01	22·18	21·11	21·06	286·68	19·63
	29	17·16	255·57	22·09	19·75	21·27	286·02	18·37
	31	16·90	255·09	22·00	18·35	21·48	285·24	17·06
Feb.	2	16·59	254·56	21·90	16·91	21·68	284·28	15·71
	4	16·27	253·99	+21·80	−15·42	+21·88	282·99	14·32
	6	15·93	253·36	21·69	13·87	22·07	282	12·89
	8	15·56	252·68	21·58	12·26	22·26	280	11·42
	10	15·15	251·97	21·47	10·63	22·44	277	9·92
	12	14·73	251·23	21·36	8·97	22·62	274	8·42
	14	14·29	250·47	+21·25	− 7·28	+22·79	270	6·92
	16	13·83	249·67	21·13	5·55	22·95	264	5·45
	18	13·35	248·85	21·01	3·80	23·11	252	4·08
	20	12·87	248·00	20·90	2·01	23·26	231	3·01
	22	12·38	247·16	20·79	− 0·23	23·41	197	2·63
	24	11·89	246·33	+20·69	+ 1·54	+23·56	166	3·21
	26	11·40	245·50	20·59	3·31	23·70	147	4·38
	28	10·91	244·69	20.49	5·07	23·84	136	5·78
Mar.	2	10·43	243·89	20·40	6·81	23·97	130	7·27
	4	9·97	243·10	20·30	8·55	24·09	126	8·78
	6	9·52	242·35	+20·21	+10·25	+24·20	124	10·29
	8	9·10	241·64	20·14	11·91	24·30	122	11·79
	10	8·69	240·96	20·08	13·54	24·40	120	13·27
	12	8·30	240·32	20·02	15·13	24·49	118·85	14·70
	14	7·93	239·72	19·97	16·69	24·58	117·65	16·12
	16	7·58	239·18	+19·93	+18·18	+24·66	116·68	17·48
	18	7·28	238·69	19·91	19·63	24·74	115·88	18·79
	20	7·01	238·25	19·90	21·03	24·82	115·18	20·05
	22	6·77	237·85	19·90	22·39	24·89	114·53	21·29
	24	6·56	237·52	19·91	23·69	24·95	113·97	22·45
	26	6·38	237·25	+19·93	+24·92	+25·01	113·48	23·57
	28	6·23	237·03	19·97	26·11	25·06	113·06	24·64
	30	6·12	236·86	+20·02	+27·25	+25·10	112·70	25·65

Greenwich Noon.	⊙	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.			
1901.	°	m	″	″	°	h	m	h	m
Jan. 15	52·28	6·894	11·58	0·61	43·62	21	38·21	22	15·37
17		6·779	11·78	0·57	25·52	22	52·46	23	29·48
19		6·668	11·97	0·53	7·47	...		0	6·43
21		6·561	12·17	0·49	349·47	0	43·30	1	20·11
23	55·80	6·458	12·36	0·45	331·53	1	56·85	2	33·52
25		6·361	12·55	0·41	313·65	3	10·11	3	46·65
27		6·269	12·73	0·37	295·85	4	23·15	4	59·59
29		6·182	12·91	0·33	278·09	5	35·98	6	12·32
31	59·31	6·101	13·08	0·29	260·37	6	48·61	7	24·86
Feb. 2		6·024	13·25	0·25	242·70	8	1·05	8	37·19
4		5·954	13·41	0·21	225·07	9	13·25	9	49·27
6		5·892	13·55	0·18	207·51	10	25·26	11	1·21
8	62·81	5·836	13·68	0·14	189·99	11	37·12	12	12·99
10		5·784	13·80	0·11	172·49	12	48·82	13	24·61
12		5·740	13·91	0·08	155·02	14	0·36	14	36·07
14		5·704	14·00	0·05	137·57	15	11·78	15	47·46
16	66·30	5·676	14·07	0·03	120·16	16	23·12	16	58·76
18		5·656	14·12	0·01	102·78	17	34·39	18	10·01
20		5·642	14·15	0·00	85·40	18	45·62	19	21·22
22		5·634	14·17	0·00	68·03	19	56·82	20	32·42
24	69·80	5·634	14·17	0·00	50·64	21	8·03	21	43·67
26		5·643	44·15	0·01	33·25	22	19·33	22	55·01
28		5·660	14·10	0·02	15·84	23	30·71	...	
Mar. 2		5·684	14·04	0·04	358·41	0	6·43	0	42·17
4	73·29	5·715	13·97	0·07	340·97	1	17·93	1	53·72
6		5·752	13·88	0·11	323·52	2	29·54	3	5·41
8		5·797	13·77	0·15	306·04	3	41·31	4	17·27
10		5·850	13·65	0·19	288·49	4	53·27	5	29·34
12	76·78	5·908	13·51	0·23	270·89	6	5·45	6	41·62
14		5·972	13·36	0·28	253·24	7	17·83	7	54·10
16		6·041	13·21	0·33	235·54	8	30·40	9	6·76
18		6·118	13·05	0·38	217·79	9	43·19	10	19·67
20	80·28	6·200	12·88	0·42	199·99	10	56·21	11	32·81
22		6·286	12·71	0·46	182·14	12	9·48	12	46·21
24		6·376	12·53	0·50	164·24	13	23·00	13	59·85
26		6·470	12·34	0·54	146·28	14	36·76	15	13·73
28	83·79	6·570	12·15	0·57	128·26	15	50·75	16	27·83
30		6·675	11·96	0·60	110·19	17	4·97	17	42·16

Greenwich Noon. 1901.	P.	L—O.	B.	A—L.	*B.*	Q.	E.
Apr. 1	6°·05	236°·74	+20°·09	+28°·3	+425°·13	112°·36	26°·61
3	6·01	236·67	20·15	29·38	25·16	112·06	27·53
5	5·99	236·65	20·22	30·38	25·18	111·80	28·40
7	6·01	236·68	20·31	31·32	25·20	111·58	29·23
9	6·05	236·76	20·41	32·22	25·21	111·39	30·00
11	6·12	236·89	+20·52	+33·06	+25·21	111·23	30·74
13	6·23	237·07	20·64	33·86	25·21	111·10	31·43
15	6·38	237·30	20·77	34·61	25·20	111·00	32·08
17	6·55	237·57	20·91	35·32	25·18	110·92	32·69
19	6·74	237·89	21·05	35·98	25·16	110·86	33·26
21	6·96	238·24	+21·20	+36·61	+25·13	110·81	33·79
23	7·20	238·63	21·36	37·20	25·10	110·78	34·29
25	7·45	239·06	21·52	37·75	25·06	110·76	34·76
27	7·73	239·53	21·68	38·26	25·01	110·76	35·19
29	8·03	240·03	21·85	38·74	24·96	110·79	35·59
May 1	8·36	240·57	+22·02	+39·18	+24·90	110·83	35·95
3	8·70	241·14	22·20	39·60	24·83	110·88	36·29
5	9·06	241·73	22·38	39·99	24·75	110·93	36·61
7	9·44	242·37	22·56	40·34	24·67	110·98	36·90
9	9·83	243·03	22·74	40·66	24·58	111·03	37·16
11	10·24	243·73	+22·93	+40·95	+24·49	111·08	37·39
13	10·67	244·46	23·12	41·21	24·39	111·14	37·61
15	11·11	245·21	23·30	41·45	24·28	111·21	37·80
17	11·56	245·99	23·48	41·66	24·17	111·29	37·97
19	12·03	246·80	23·66	41·83	24·05	111·37	38·13
21	12·51	247·63	+23·83	+41·99	+23·92	111·46	38·28
23	13·00	248·48	24·00	42·13	23·78	111·56	38·41
25	13·49	249·35	24·16	42·25	23·64	111·65	38·50
27	14·00	250·24	24·33	42·34	23·49	111·74	38·56
29	14·53	251·16	24·49	42·41	23·34	111·84	38·62
31	15·06	252·11	+24·65	+42·44	+23·18	111·94	38·67
June 2	15·60	253·08	24·80	42·46	23·01	112·04	38·71
4	16·15	254·06	24·95	42·46	22·84	112·14	38·74
6	16·71	255·06	25·09	42·44	22·66	112·23	38·75
8	17·27	256·08	25·22	42·40	22·48	112·33	38·75
10	17·84	257·12	+25·35	+42·35	+22·29	112·42	38·73
12	18·41	258·18	25·47	42·27	22·09	112·51	38·70
14	18·98	259·25	+25·58	+42·19	+21·88	112·60	38·67

Greenwich Noon.			Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.			
					q	ω_0				
1901.		°	m	"	"	°	h	m	h	m
Apr.	1		6.784	11.77	0.63	92.07	18	19.41	18	56.72
	3		6.894	11.58	0.66	73.90	19	34.08	20	11.50
	5	87.31	7.006	11.39	0.69	55.67	20	48.97	21	26.50
	7		7.124	11.20	0.71	37.39	22	4.08	22	41.72
	9		7.244	11.02	0.74	19.06	23	19.41	23	57.16
	11		7.366	10.84	0.76	0.68	...		0	34.96
	13	90.84	7.490	10.66	0.78	342.25	1	12.81	1	50.71
	15		7.614	10.48	0.80	323.79	2	28.66	3	6.66
	17		7.741	10.30	0.82	305.28	3	44.70	4	22.78
	19		7.870	10.13	0.84	286.73	5	0.91	5	39.08
	21	94.39	8.001	9.96	0.85	268.13	6	17.30	6	55.56
	23		8.134	9.80	0.86	249.48	7	33.87	8	12.22
	25		8.269	9.65	0.87	230.79	8	50.61	9	29.04
	27		8.404	9.49	0.87	212.07	10	7.51	10	46.01
	29	97.95	8.540	9.34	0.88	193.32	11	24.55	12	3.12
May	1		8.676	9.20	0.88	174.54	12	41.72	13	20.36
	3		8.813	9.06	0.88	155.73	13	59.04	14	37.75
	5		8.950	8.92	0.89	136.88	15	16.50	15	55.29
	7	101.54	9.088	8.78	0.89	118.00	16	34.12	17	12.97
	9		9.226	8.65	0.88	99.08	17	51.86	18	30.78
	11		9.364	8.52	0.88	80.13	19	9.74	19	48.73
	13		9.502	8.40	0.88	61.15	20	27.75	21	6.80
	15	105.15	9.640	8.28	0.87	42.15	21	45.88	22	24.98
	17		9.778	8.16	0.87	23.12	23	4.11	23	43.27
	19		9.916	8.05	0.87	4.07	...		0	22.45
	21		10.054	7.94	0.86	344.99	1	1.66	1	40.90
	23	108.79	10.192	7.83	0.86	325.89	2	20.16	2	59.45
	25		10.329	7.73	0.85	306.76	3	38.77	4	18.12
	27		10.466	7.63	0.84	287.61	4	57.48	5	36.86
	29		10.602	7.53	0.83	268.44	6	16.26	6	55.69
	31	112.45	10.738	7.43	0.82	249.25	7	35.14	8	14.61
June	2		10.873	7.34	0.81	230.04	8	54.10	9	33.61
	4		11.006	7.25	0.80	210.81	10	13.14	10	52.69
	6		11.139	7.16	0.79	191.56	11	32.26	12	11.85
	8	116.15	11.271	7.08	0.78	172.29	12	51.46	13	31.10
	10		11.403	7.00	0.77	153.01	14	10.76	14	50.44
	12		11.534	6.92	0.76	133.70	15	30.14	16	9.86
	14		11.664	6.84	0.75	114.38	16	49.60	17	29.34

Greenwich Noon.	P.	L—Ω.	B.	A—L.	β.	Q.	R.
1901.	°	°	°	°	°	°	°
June 16	19·55	260·34	+25·68	+42·08	+21·67	112·68	38·62
18	20·13	261·44	25·77	41·96	21·45	112·75	38·56
20	20·70	262·55	25·86	41·83	21·23	112·82	38·49
22	21·28	263·68	25·93	41·68	21·00	112·89	38·41
24	21·86	264·82	26·00	41·52	20·77	112·95	38·32
26	22·44	265·98	+26·06	+41·34	+20·53	113·01	38·23
28	23·03	267·16	26·10	41·14	20·28	113·06	38·12
30	23·62	268·36	26·14	40·92	20·02	113·12	38·00
July 2	24·21	269·56	26·16	40·70	19·76	113·17	37·88
4	24·79	270·77	26·17	40·47	19·49	113·22	37·75
6	25·37	271·99	+26·18	+40·23	+19·22	113·25	37·62
8	25·94	273·22	26·17	39·98	18·94	113·27	37·48
10	26·51	274·46	26·15	39·71	18·66	113·29	37·33
12	27·08	275·71	26·12	39·44	18·37	113·30	37·17
14	27·65	276·97	26·08	39·15	18·07	113·31	37·01
16	28·21	278·24	+26·02	+38·86	+17·77	113·31	36·85
18	28·76	279·52	25·95	38·55	17·46	113·30	36·68
20	29·30	280·80	25·86	38·25	17·15	113·29	36·51
22	29·83	282·09	25·77	37·93	16·83	113·27	36·33
24	30·36	283·39	25·67	37·60	16·50	113·25	36·14
26	30·88	284·69	+25·55	+37·28	+16·17	113·21	35·95
28	31·38	286·00	25·42	36·94	15·84	113·16	35·75
30	31·87	287·31	25·28	36·60	15·50	113·11	35·55
Aug. 1	32·35	288·63	25·12	36·25	15·15	113·04	35·34
3	32·83	289·96	24·95	35·89	14·80	112·96	35·13
5	33·30	291·29	+24·76	+35·53	+14·44	112·88	34·92
7	33·75	292·62	24·56	35·18	14·08	112·79	34·71
9	34·19	293·95	24·35	34·82	13·72	112·69	34·49
11	34·61	295·29	24·12	34·46	13·35	112·57	34·27
13	35·01	296·63	23·88	34·09	12·97	112·45	34·04
15	35·39	297·97	+23·62	+33·73	+12·59	112·32	33·81
17	35·76	299·31	23·35	33·36	12·20	112·18	33·57
19	36·11	300·66	23·08	32·98	11·81	112·03	33·33
21	36·44	302·01	22·79	32·61	11·41	111·87	33·09
23	36·76	303·36	22·49	32·23	11·01	111·70	32·85
25	37·06	304·71	+22·17	+31·86	+10·60	111·52	32·60
27	37·35	306·06	21·84	31·48	10·19	111·33	32·35
29	37·61	307·40	+21·50	+31·12	+ 9·78	111·13	32·10

Greenwich Noon.	⊙	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.	
1901.	°	m	"	"	°	h m	h m
June 16	119·88	11·793	6·77	0·74	95·05	18 9·09	18 48·86
18		11·921	6·70	0·73	75·71	19 28·64	20 8·43
20		12·048	6·63	0·72	56·35	20 48·24	21 28·07
22		12·174	6·56	0·71	36·97	22 7·91	22 47·77
24	123·65	12·300	6·49	0·70	17·57	23 27·64	...
26		12·424	6·42	0·69	358·16	0 7·53	0 47·44
28		12·547	6·36	0·68	338·73	1 27·37	2 7·32
30		12·669	6·30	0·67	319·29	2 47·28	3 27·26
July 2	127·46	12·790	6·24	0·66	299·84	4 7·25	4 47·26
4		12·909	6·18	0·65	280·39	5 27·29	6 7·32
6		13·027	6·12	0·64	260·92	6 47·35	7 27·39
8		13·144	6·07	0·63	241·45	8 7·44	8 47·49
10	131·31	13·260	6·02	0·62	221·96	9 27·55	10 7·60
12		13·375	5·97	0·61	202·47	10 47·67	11 27·75
14		13·489	5·92	0·60	182·97	12 7·83	12 47·92
16		13·601	5·87	0·59	163·46	13 28·02	14 8·13
18	135·21	13·711	5·82	0.58	143·94	14 48·26	15 28·41
20		13·821	5·78	0·57	124·41	16 8·57	16 48·74
22		13·930	5·73	0·56	104·88	17 28·92	18 9·11
24		14·037	5·69	0·54	85·34	18 49·31	19 29·51
26	139·16	14·143	5·65	0·53	65·79	20 9·71	20 49·91
28		14·248	5·61	0·52	46·24	21 30·11	22 10·31
30		14·351	5·57	0·51	26·68	22 50·52	23 30·73
Aug. 1		14·453	5·53	0·50	7·12	...	0 10·94
3	143·15	14·553	5·49	0·49	347·56	0 51·15	1 31·37
5		14·652	5·45	0·49	328·00	2 11·59	2 51·82
7		14·750	5·41	0·48	308·43	3 32·06	4 12·30
9		14·847	5·38	0·47	288·86	4 52·55	5 32·80
11	147·20	14·943	5·34	0·46	269·28	6 13·06	6 53·32
13		15·037	5·31	0·45	249·69	7 33·58	8 13·84
15		15·129	5·27	0·45	230·11	8 54·10	9 34·35
17		15·220	5·24	0·44	210·53	10 14·61	10 54·87
19	151·30	15·310	5·21	0·43	190·94	11 35·12	12 15·38
21		15·399	5·18	0·42	171·36	12 55·64	13 35·89
23		15·487	5·15	0·42	151·78	14 16·15	14 56·41
25		15·573	5·12	0·41	132·20	15 36·67	16 16·93
27	155·45	15·658	5·09	0·40	112·62	16 57·19	17 37·46
29		15·742	5·07	0·39	93·03	18 17·72	18 57·98

Greenwich Noon.	P.	L—O.	B.	Λ—L.	*B*.	Q.	E.
1901.	°	°	°	°	°	°	°
Aug. 31	37·86	308·75	+21·14	+30·75	+ 9·36	110·91	31·85
Sept. 2	38·08	310·09	20·77	30·39	8·94	110·68	31·59
4	38·29	311·44	20·38	30·02	8·51	110·44	31·33
6	38·48	312·79	19·99	29·65	8·08	110·19	31·07
8	38·64	314·13	19·58	29·29	7·65	109·93	30·81
10	38·78	315·47	+19·16	+28·93	+ 7·22	109·66	30·55
12	38·88	316·80	18·72	28·59	6·78	109·37	30·28
14	38·96	318·11	18·26	28·26	6·33	109·07	30·01
16	39·01	319·41	+17·79	+27·95	+ 5·88	108·76	29·74

This ephemeris has been computed with the same constants as those for the last two oppositions. The position of the north pole of *Mars* is assumed to be R.A. 317°·17, N.P.D. 37°·42 at the beginning of the ephemeris, and R.A. 317°·18, N.P.D. 37°·41 at the end of it. These values are those deduced by Struve from observations of the satellites. I have continued to use them in the absence of any suggestions to the contrary.

P. denotes the position angle of the axis of *Mars*; L—O + 180° the Right Ascension of the Earth referred to the plane of *Mars*' equator, and reckoned from O, the point of the vernal equinox of *Mars*' northern hemisphere; Λ—O + 180°, the corresponding quantity for the Sun; B, *B*, the declinations of the Earth and Sun reckoned from the plane of *Mars*' equator; Q, the position angle of the greatest defect of illumination; *q*, the amount of the greatest defect of illumination; E, the areocentric angle between the Earth and Sun.

Thus Λ—L is the angle between the meridians of *Mars* which are central to the Earth and to the Sun; the point where an image of the Sun should be looked for is distant $\frac{1}{2}(\Lambda - L)$ in longitude from the centre of the disc, on the side towards the fully illuminated limb, and is in areocentric latitude $\frac{1}{2}(B + \mathit{B})$.

The column ⊙, given now for the first time, is the areocentric longitude of the Sun referred to the plane of *Mars*' orbit, and reckoned from O, the point of the vernal equinox of *Mars*' northern hemisphere. The object of this column is to ascertain readily the season on *Mars*. ⊙ = 0° corresponds to March 20 on the Earth, ⊙ = 30° to April 20, and so on.

The diameter of the planet at distance unity is assumed (as before) to be 9″·60, that used in the *Nautical Almanac* being 9″·36.

The zero meridian and period of rotation have been carried on unchanged from Mr. Marth's last ephemeris, the assumed sidereal rotation in 24 hours being 350°·89202. I should be glad to have observations of the transits of any well-determined

Greenwich Noon.	⊙	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.			
1901.	°	m	″	″	°	h	m	h	m
Aug. 31		15·824	5·04	0·38	73·45	19	38·24		
								20	18·51
Sept. 2		15·905	5·02	0·37	53·86	20	58·77		
								21	39·02
4	159·66	15·985	4·99	0·37	34·28	22	19·27		
								22	59·52
6		16·063	4·97	0·36	14·71	23	39·77		
								...	
8		16·140	4·94	0·35	355·13	0	20·02		
								1	0·26
10		16·216	4·92	0·34	335·56	1	40·51		
								2	20·75
12	163·93	16·292	4·90	0·33	315·98	3	1·00		
								3	41·24
14		16·367	4·88	0·33	296·41	4	21·48		
								5	1·72
16		16·440	4·86	0·32	276·84	5	41·96		

points across the centre of the disc communicated to me, as a check on the accuracy of the values assumed in the ephemeris.

The last two columns contain the Greenwich Mean Time of transit of the zero meridian across the centre of the disc, the times being given for the intermediate days as well as for those given in the date column. They are tabulated to $0^m{\cdot}01$, but the last figure given is only approximate.

The quantities are to be interpolated directly from the ephemeris for the time for which they are required, the equation of light having been already applied.

The vernal equinox of *Mars'* northern hemisphere occurs 1900 September $24^d{\cdot}3$ and the summer solstice 1901 April $11^d{\cdot}1$.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.*:
1900 *January* 10.

Erratum in Prof. E. W. Brown's paper, vol. lx. p. 124, lines 18, 19,

for "parts of the ratio of the mean motions,"
read "mean motions of the perigee and node."

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. JANUARY 12, 1900—(*continued*). No. 4

On the Probable Motion of the Annular Nebula in Lyra (*M* 57) *and the peculiarities in the Focus for the Planetary Nebulæ and their Nuclei.* By E. E. Barnard.

In *Ast. Nach.* 2186, Bd. 92, Professor Hall has given measures of some of the small stars near the annular nebula of *Lyra* (M 57), made with the 26-inch at Washington in 1877 July and August.

I have taken the means of his various measures which are here given. For reference he has used the 12-magnitude star close following the nebula except for the stars f_1 and f_2.

a and b	225°.5	93″.90 (2n)	Mag. 14
a „ c	268.0	115.83 (2n)	„ 13.14
a „ d	286.9	138.58 (2n)	„ 12.13
a „ e	292.6	122.90 (2n)	„ 12
a „ f	313.7	101.79 (2n)	„ 13.14
a „ g	350.5	77.18 (2n)	„ 13
f „ f_1	253.3	3.96 (2n)	„ 13.14
f „ f_2	364.8	17.31 (2n)	„ 14.15

The different nights' measures, in the main, are very consistent except in the case of f and f_2, where the distances differ by one second.

Professor Hall was unable to see any star nearer the nebula than these, and could see no star anywhere within the nebula.

In 1891 Mr. Burnham measured the central star or nucleus with reference to the star *a* with the 36-inch. His measures are very consistent. and are undoubtedly the best that could be made of such an object. He mentions the fact that "all the measures were made under very favourable conditions, and the central star well seen."

On account of their importance I will give his measures in full (they are from *Pub. Lick Obs.*, vol. ii. 1894). The measures refer the star to the nucleus.

	°	″	m	m
1891·326	88·2	61·64	15·5	12·0
·416	87·8	61·44	15·5	13·5
·419	86·5	61·56	15·5	12·0
·518	88·4	62·28	15·0	13·0
·559	88·0	61·56	15·5	11·5
1891·45	87·8	61·69	15·4	12·4

These are the only measures of the nucleus that I know of. It is to be regretted that the admirable example shown by Mr. Burnham in measuring objects of this class is not more fully followed out when the micrometer is available. A mere sketch —no matter how carefully it is made—of the relative position of the nucleus of this object and the surrounding stars has no value whatever for the vital points in question, such as motion, &c. For the first time, therefore, we have the position of the nucleus fixed definitely for reference in future observations.

There is one point lacking, however, and that is, should any relative change occur it could not readily be seen whether it belonged to the nucleus or to *a*, or to both.

The excellent and valuable measures made by Hall in 1877 of the position of *a* with reference to surrounding stars have definitely prepared for this question.

I have been re-measuring some of the planetary nebulæ measured by Mr. Burnham with the 36-inch. The measures have been in very close agreement with his, thus showing no certain motion in the interval of some eight years, except possibly in the present instance.

During 1898 and 1899 I measured the relative position of the nucleus of M 57 and the star *a* with the 40-inch.

When the seeing permits it, the nucleus, in the great telescope, is distinctly seen, and is subject to fairly accurate measurement.

As the question of possible motion of the nebula has come up in the measures, I have measured the position of the nucleus from three other stars, besides repeating the measures of *a*.

These measures have been made with the utmost care, and I believe will fairly represent the relative position of the nucleus at the present time.

The Nucleus of M 57 and the Star a.

1898. July 12	1898·531	88°·98	60″·96
Aug. 8	·605	88·75	60·63
9	·607	88·50	60·87
10	·610	88·74	60·73
29	·662	88·90	60·67
	1898·60	88·77	60·77
1899. June 16	1899·459	89°·12	60″·79
18	·464	88·90	60·70
24	·481	89·67	60·52
July 1	·500	88·74	60·88
2	·503	89·27	60·74
	1899·48	89·14	60·73

The Nucleus and the Star b.

1899. July 29	1899·577	185°·46	65″·15
31	·582	185·40	65·15
Aug. 1	·585	185·25	65·07
	1899·58	185·37	65·12

The Nucleus and the Star c.

1899. July 8	1899·519	268°·27	54″·91
10	·525	266·72	55·22
16	·541	267·78	54·85
	1899·53	267·59	54·99

The Nucleus and the Star e.

1899. June 24	1899·481	312°·55	71″·14
July 1	·500	312·08	70·91
2	·503	312·50	71·14
	1899·49	312·38	71·06

It will be seen that my measures of the nucleus and *a* differ from Mr. Burnham's by about 1° in angle and 1″ in distance. While this is a small quantity for two different observers and telescopes dealing with a difficult object of this kind, yet it is worthy of consideration when the power of the instruments is considered, and when the two observers are as consistent as they always are in measurements like these. I am therefore under the impression that this apparent relative change may be a real

one, and the question comes up whether it is due to change in the star *a* or in the nucleus.

To test the stability of *a* I have repeated Professor Hall's measures of 1877, and have added three other stars to the list which have not previously been measured.

Of these stars the following are my estimates of magnitude with the 40-inch :—

	m		m
a	12·2 (3)	f_1	13·9 (2)
b	13·8 (2)	f_2	14·5 (2)
c	14·0 (3)	*g*	13·7 (2)
d	13·5 (3)	*h*	12·8 (3)
e	13·2 (3)	*k*	15·7 (4)
f	13·7 (3)	*p*	16·5 (2)*

* The position in reference to the nebula makes it difficult to decide on the magnitude of this star *p*. It is perhaps as bright as the $15\frac{1}{2}$ magnitude.

Following are the measures :—

a and b.

1899.		°	″
July 1	1899·500	225·50	93·54
2	·503	226·02	93·88
8	·519	225·77	93·65
	1899·51	225·76	93·69

a and c.

1899.		°	″
June 26	1899·486	268·75	115·73
July 1	·500	268·81	115·59
8	·519	268·77	115·83
	1899·50	268·78	115·72

a and d.

1899.		°	″
June 24	1899·481	286·59	*
26	·486	287·17	137·59
July 2	·503	287·12	137·77
8	·519	286·97	137·95
	1899·50	286·96	137·77

* Seeing too poor for distance.

a and e.

1899.		°	″
June 17	1899·462	292·91	122·27
24	·481	292·72	122·30
	1899·47	292·81	122·28

a and g.

1899.		°	″
June 17	1899·462	350·91	75·90*
18	·465	350·60	76·34*
July 10	·525	350·75	76·78
Aug. 6	·600	350·85	76·00
	1899·51	350·78	76·25

* Single distance; faint and difficult.

a and f (the following and brightest of two).

1899.		°	″
June 26	1899·486	315·47	100·07
July 8	·519	315·32	100·11
	1899·50	315·39	100·09

f and a Star close preceding $=f_1$.

1899.		°	″
July 8	1899·519	261·10	5·11
9	·522	264·70	4·97
10	·525	263·05	4·62
	1899·53	262·95	4·90

f and a Star north $=f_2$.

1899.		°	″
July 8	1899·519	2·93	17·88
10	·525	3·92	17·89
	1899·52	3·42	17·88

Following are the three additional stars not previously bserved :—

a and h.

1899.		°	″
June 16	1899·459	148·25	70·70
17	·462	148·23	70·36*
24	·481	147·94	70·80
	1899·47	148·14	70·62

* Clock drifting badly.

a and h.

1899.		°	″
July 31	1899·582	195·70	85·56
Aug. 1	·585	195·85	83·57*
5	·596	196·30	84·91
	·599	195·63	85·31
	604	195·82	85·25
	1899·59	195·86	85·26

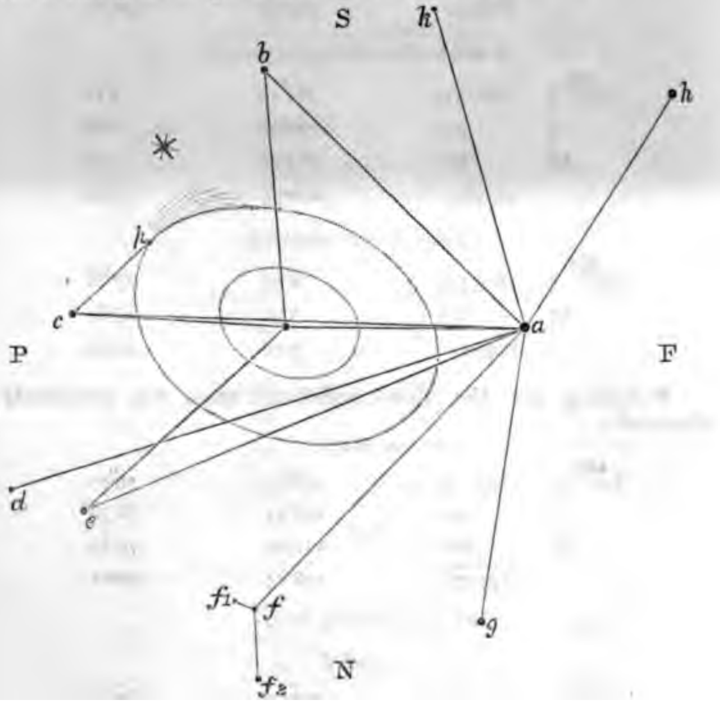
* Reject the distance.

c and p (in preceding edge of Nebula).

1899. July	8	1899·519	133°·30	27″·08
	10	·525	133·38	27·46
		1899·52	133·34	27·27

This star *p* is *exactly* on the north preceding edge of the nebula. The outline of the nebula would cut *exactly* through the star.

There is a 17th magnitude star—at the limit of vision for the 40-inch, and hence a good subject for photography—in 218°± 60″± referred to the nucleus. This star was too faint to measure accurately, and I have taken its place from a sketch. On the diagram its place is marked with a ×.



Micrometrical Measures of M 57 and neighbouring stars.

The star *k* for some reason is very difficult to measure—more so than its magnitude would warrant. It has a dull appearance, and does not seem so well defined as stars of similar magnitude near. It looks as if it might be either a very small nebula or nebulous star.

In comparing these measures with Hall's made twenty-two

years ago there appears to be some change in some of the stars, but there is no very decided motion shown in the position of *a*.

The star *f* seems decidedly to be in motion when compared with f_1 and *a*. The position angle of f_1 has increased about 10°, and the distance about 1″, while the distance *a f* seems to have diminished over $1\frac{1}{2}''$.

If we reduce the two sets of measures of *a* and *f* to $\Delta\alpha$ and $\Delta\delta$, we get :—

Hall	$\Delta\alpha$	73·59″	$\Delta\delta$	70·32″
Barnard		70·29		71·25
		3·30		0·93

The same for *f* and f_1 gives :—

Hall	3·79″	1·14″
Barnard	4·86	0·60
	1·07	0·54

while for *f* and f_2 the discordances are within the possible errors of measurement.

There seems to be possibly some motion in *d* also ; but it is uncertain. Some of the apparent change in *f* may be due to change in *a*, which might also account for the lessening of the distance *a d*. It seems to be difficult just now to definitely locate the motion, but it appears certain that motion is shown to exist in one or more of the stars.

The measures of *a* and *c*, however, show that the discrepancy in Mr. Burnham's measures of the nucleus and mine cannot be due to any motion in *a*, for it would also affect the distance *a c*, which does not seem to have sensibly changed in the past twenty-two years.

If the apparent motion shown by Mr. Burnham's measures and mine is real it next becomes a question whether the motion can be said to be in the nebula—that is, is the central star a real nucleus or an accidental projection ? Everything points to its being a part of the nebula—that is, the nucleus. It is shown by photography to be highly actinic, though visually a very faint body, so that the relative photographic quality of its light is greater than that of other faint stars near.* It is almost certain, then, that if motion is found to exist in this central star it is a motion of the nebula itself.

I would suggest that the question of motion in this nebula is one singularly suited for the photographic plate to decide, because of the high actinic power of the nucleus. I should be very glad to see measures made of any existing photographs of this object, and I hope that the present paper will call attention to the

* I find that Dr. Scheiner (*Ast. Nach.* 3086), and Prof. Keeler (*Ast. Nach.* 3111), have shown that the central star M 57 must in reality be the nucleus of the nebula.

importance of securing accurate photographic data for the future investigation of the nebula and its surroundings.

The question of motion of the star *f* is an important one on account of its faintness.

So far as the visual work is concerned, the nucleus is now thoroughly tied up with the stars *a*, *b*, *c*, and *e*, and observations five or six years hence ought to show conclusively if the supposed motion is real. If there are any measurable photographs made six or eight years ago, they would be rather conclusive compared with others made now.

All the measures with the 40-inch have been reduced with a screw value of 9″·677. A final reduction of all the determinations running over some three years will slightly reduce this value, but not to materially affect the present measures.

In *A.N.* 3200 I have given an account (with sketch) of the discovery with the 36-inch, on 1893 October 2, of a rather conspicuous nebula, only 4′ from the centre of the ring nebula. I have measured this object with the 40-inch, in which it is decidedly conspicuous.

*Nucleus of M 57 and Nebula.**

		°	″
1899 July 16	1899·541	303·9	244·47
17	·544	303·8	244·22
	1899·54	303·8	244·34

The measures in 1893 (two nights) gave :—

Nucleus and Nebula.

1893·76	302°·8	243″·68

During 1893 and 1894 I secured a series of measures of the dimensions of M 57 and the position angle of the major axis. These were published in *Ast. Nach.* 3354. I will here repeat the mean results of these measures for completeness in the present paper.

Position Angle of the Major Axis.

1893·95 ... ... 65°·43 (9 nights)

Outer Major Diameter.

1894·44 ... ... 80″·89 (5 nights)

Inner Major Diameter.

1893·87 ... ... 36″·52 (5 nights)

Outer Minor Diameter.

1894·12 ... ... 58″·81 (6 nights)

* In an article in the October *Astrophysical Journal* Professor Keeler says that his photographs of the annular nebula show this small nebula to be a left-handed spiral.

Inner Minor Diameter.

1893·87 ... ... $29''\cdot36$ (5 nights)

All the measures in this paper depend on double distances. From four to five settings for the position angles and three to four settings on each side of the fixed wire for the distances were made.

The nebula is a beautiful object in the great telescope; though the ring appears to be unequally bright in places, but little detail can be made out on it with certainty. There is a faint brushing out of the light from the south preceding edge of the ring. Under the best conditions the interior of the ring has appeared of unequal brightness. The light of the ring itself, however, blinds one's eye to the details on the interior, so that it is not possible to speak with certainty of the form of these details.

In *Comptes Rendus*, No. 5, for 1899 July 31 is a paper by MM. Bourget, Montangerand, and Baillaud calling attention to important changes which they find to have occurred in this nebula in the past ten years.

According to these observers the central star or nucleus has increased greatly in brightness of late years.

These gentlemen, observing the nucleus on 1899 July 8 with the great reflector of the Toulouse Observatory, of $0^m\cdot83$ (33 inches) aperture, found it an easy object. From this observation, and from photographs made in 1890 and 1899, they concluded great changes had taken place, both in the form of the nebula and in the brightness of the central star.

I have been familiar with this object for upwards of ten years, as it has appeared in the 36-inch at the Lick Observatory and in the 40-inch here. In 1893 and 1894 I made a special study of the nebula with the 36-inch, and measured all its dimensions on a number of nights, and specially noted the appearance of the central star.

So far as visual observations go, I am unable to verify the striking changes indicated by the Toulouse observations. Indeed, on the very night that those observations were made—1899 July 8—I measured the nucleus with the 40-inch, and saw nothing different from what I have seen for the past ten years. On that night I noted the nucleus as about 15½ or 16^m from a direct estimate, and from comparison with a star outside the ring. Mr. Burnham's estimate in 1891 made it 15·4 magnitude.

The nucleus of this object is quite like that of the *Andromeda* nebula (M 31) in the uncertainty and deception in fixing any change that might occur in its brightness. The fact that the nucleus is seen on a nebulous background makes steadiness of the atmosphere a most important factor in its distinctness—far more so than in the case of an ordinary star in the open sky. When the seeing is exceptionally good, the nucleus appears with a distinctness strikingly in contrast with its ordinary condition,

so much so that one has to guard against deception in supposing a real change of light. So much do the atmospheric conditions enter into this question of change in the nucleus of a nebula that the frequent observations of variability in these objects might be properly translated into "fine seeing," "good seeing," "poor seeing," and "bad seeing" in the decreasing order of reported brightness of the object.

The observers at Toulouse also speak of their photographs having likewise proved that the central star had increased greatly in brightness. They do not say, however, that the nucleus is brighter than stars on the same plate which it had equalled in 1890. Such might be considered a test of actual change, though this in itself is also subject for criticism from the very causes mentioned above, though not to the same extent. The fact, however, that a photograph of to-day shows the star quicker than one nine or ten years ago, might be accounted for by an increase of sensitiveness of the plate alone.

Since writing the main portion of this paper I have seen some very fine photographs of M 57 taken by Professor Keeler with the 37-inch Crossley reflector of the Lick Observatory. These beautiful photographs show the very faint star I have mentioned as being essentially at the limit of the 40-inch, and also several stars that are apparently fainter on the photographs. The brushing out of the nebulosity from the south preceding edge of the ring is shown, and a similar appearance from the north following edge. These photographs also show a second star in the ring north preceding the central star. The star *p* is also shown. I have never been sure of seeing the second star in the ring, but have thought at times that I could see it faintly. This star is difficult visually, not only on account of actual faintness, but also from the fact that it is near the inner edge of the bright ring which blinds one to its feeble light. It was seen at the Lick Observatory, and described in a paper on the nebula by Professors Holden and Schaeberle in *M.N.* vol. xlviii. p. 383.

In a paper in the *Astrophysical Journal* for 1899 October Professor Keeler seems to infer that the star *p* is not a real star, but a condensation in the nebula. This seems hardly probable, for it is exactly on the extreme edge of the nebula visually, and I have been struck with its perfectly stellar appearance when measuring it, and have so recorded it. I think it must be but an ordinary star, and that its close proximity to the nebula is quite accidental.

In a drawing of M 57, made with the 4-foot reflector, issued in a circular dated "Bradstones, Sandfield Park, near Liverpool, 1860 November 19," Lassell shows the central star (not, however, exactly in its true position), and refers to it as being near the limit of vision of his telescope.

Peculiarities in the Focus for the Planetary Nebulæ.

It is a well-known fact that the planetary nebulæ come to a focus outside the focus for an ordinary star. This, of course, is due to peculiarities in their spectra.

In examining the different planetary nebulæ, I have made some experiments in this line with the 40-inch, which may be of general interest.

With a magnifying power of 1300 diameters in these observations, the nebula was brought to the best focus, and a scale of inches on the focussing tube read. This would be repeated for the nucleus and also for an ordinary star. The result so far has been tabulated, and the quantities given are fractions of an inch. A plus quantity means that the first object comes to a focus further from the object glass than for the second. It is probable, by this means, we may be able to determine the wave length of the light of the nuclei of these nebulæ, which are too faint to observe with the spectroscope.

This table is preliminary, and as the subject will be carried out for all the planetary nebulæ, a more complete and accurate table will be published later. It is of sufficient interest, however, to warrant its publication here in an incomplete form.

Table of Focus for the Planetary Nebulæ.

N.G.C.	α 1860·0. h m s	δ 1860·0. ° ′	Neb.—Nucl. in.	Neb.—Star. in.	Nucl.—Star. in.
1535	4 7 44	−13 6	+0·22	+0·27	+0·05
2392	7 20 53	+21 12	+0·26	+0·29	+0·03
6543	17 58 36	+66 38	+0·18	+0·23	+0·05
6720 (M 57)	18 48 23	+32 51	+0·20	+0·30	+0·10
6826	19 41 2	+50 11	+0·22	+0·21	−0·01
7009	20 56 33	−11 55	+0·19	+0·23	+0·04
7662	23 19 11	+41 45	+0·06	+0·20	+0·14
			+0·19	+0·25	+0·06

These are in each case the means of five or more settings for focus.

The focus for Hind's celebrated crimson star is 0·06 in. outside of that for a white star nearly of same magnitude.

It will be seen from this tabulation that the planetary nebulæ so far observed give a focus for the nebula itself—about 0·19 inch farther out than its nucleus and about 0·25 inch farther out than for a fixed star. It is seen also that the nucleus comes to a focus nearer the fixed star than for the nebula and a little farther out than for the star.

The average doubtless does not mean as much as might be supposed. There seem to be individual cases which markedly differ from the others. For instance, 2392 is conspicuously

distinct from the others in the large increase of focus for its nebulosity, while the central star focus closely agrees with the average difference of nucleus-star. No. 6826 seems abnormal in this last respect. The central star seems to come out about the same for its comparison star. The minus sign is doubtless accidental. There are no details in this nebula, so that the focus for the nebula itself is rather difficult, though the settings are accordant.

No. 2392 is one of the most remarkable of the planetary nebulæ. Singularly enough, Dreyer in his careful New General Catalogue does not indicate its planetary character, nor does he indicate anything memorable about it by the usual "!!" His description is

B, S, R, ∗9M, ∗8 nf 100″.

So far as its appearance in a great telescope is concerned, it should have the usual planetary nebula sign O, with a string of exclamation points (!) running across the page.

It is a magnificent and beautiful object, a bright star of the ninth magnitude in—not exactly central—a brightish ring which is oval in form and almost incomplete in its southern part. This ring, which is well defined inside and out, is surrounded by a vacuity, and this in turn by an almost circular broad ring of light less intense than the inner ring, and with a distinct break in it north preceding. This ring breaks up into a clouded or unequal surface, and is very irregular on its inner edge but fairly uniformly circular on its outside edge. The inner ring is filled with a nebulous light which has a black spot in it, s p, the nucleus. I have found another excessively difficult star inside the inner ring south of the bright star: this minute star comes to a focus with the nebula and not with the central star. It is therefore doubtless a minute condensation of the nebula not so far advanced in stellar condition as the bright star.

I have measured all the dimensions of this nebula and am making a drawing of it.

No. 1535 is an exact duplicate of 2392, except that its central star is not so bright, and there is lacking the vacuity outside the inner ring, which is also oval in form, with a nebulous interior. Some of the other planetary nebulæ are very wonderful objects, and I am making a special study of them and hope to secure drawings and measures of the more prominent ones.

Several other of the planetary nebulæ now visible were examined for focus, among them Σ 5 (No. 6210) and Σ 6 (No. 6572), nothing could be made out of these except that they were almost identical in form and size and general appearance. The planetary nebula No. 6781 (1860·0 $19^h\ 11^m\ 38^s$, $+6°\ 17'$) is annular, the centre being dark. The star measured by Mr. Burnham (*Pub. L. O.*, vol. ii. p. 165), which he speaks of as being north of the middle, is evidently not the nucleus—it looks

more like a star. There is, however, a much fainter star at the middle which looks like the true nucleus, and is of the 16½ mag.

It is intended ultimately to compare all the comparison stars used for focus with some star whose spectrum is definitely known.

Yerkes Observatory, Williams Bay, Wisconsin:
1899 *October.*

Note.—While visiting Potsdam on 1900 February 2, I was shown an excellent photograph of M 57, taken by Dr. Scheiner with the 13-inch photographic refractor, 1894 October 29, at sidereal $21^h\ 20^m$, with an exposure of two hours. This photograph quite clearly shows the nucleus of the nebula; and, upon learning of the discrepancy in the visual measures, Dr. Scheiner very kindly measured the plate for me, and I am happy to be able through his courtesy to give here the results which, though they do not confirm any change in the nebula, are very important as a contribution to the history of the subject.

Through the further courtesy of Dr. Scheiner I was permitted to measure the plate also; but, as I am wholly inexperienced in the measurement of photographs, my measures should have very little weight compared with his, though I shall give the results of the two sets of measures, as supplied me by Dr. Scheiner.

The measures are in rectangular co-ordinates, the distances and position angles having been deduced from them by Dr. Scheiner. "Corrections for refraction and aberration have not been applied. The uncertainty by the reduction to arc may be $\pm 0''\cdot 05$, and by the error of the parallel $\pm 0^\circ\cdot 15$."

Following are the measures of this photograph referred to Star *a*:—

	S	B	Mean.
	″	″	
Co-ord. in A.R.	60·84	60·54	
Co-ord. in Decl.	0·99	1·32	
Distance (computed)... ...	60·85	60·56	60″·71
Pos. Ang. (computed) ...	89° 4′	88° 45′	88° 55′

The mean results, as shown, are position angle, $88^\circ\cdot 92$; distance, $60''\cdot 71$.†

It is still important that the nebula be carefully measured with some of our powerful telescopes six or eight years hence.

† I wish to express my great obligations to Dr. Scheiner for his kindness.

London:
1900 *February* 10.

The Exterior Nebulosities of the Pleiades, with a Drawing from the different Photographs; and on the appearance of the involved Nebulosities of the Cluster with the 40-inch Refractor. By E. E. Barnard.

In *Astronomische Nachrichten* 3253, Bd. 136, I have given an account, with a rough chart, of what I have called the exterior nebulosities of the *Pleiades*, and which were shown on photographs made with the Willard 6-inch portrait lens in 1893 December. In that paper I have stated: "For many years, during my comet-seeking, I have known of a vast and extensive, but very diffused, nebulosity north of the *Pleiades*. Other masses of this diffused matter make their presence known by a general dulling of the field when sweeping in the neighbourhood of the cluster. . . . It has been my hope during the past two or three years to sometime be able to secure a photographic impression of these vague nebulosities that I had seen in the telescope. It was evident this would require a long exposure. The mounting of our Willard lens does not permit an exposure to be carried beyond the meridian; to get sufficient time would therefore require more than one night. This past winter I have been able, by carefully inclosing the camera box in thick black cloth and by taking other precautions, to extend the exposure through two nights with success. Previous to this I gave an exposure on the *Pleiades* of four hours, which showed all the well-known nebulosities and gave faint suggestions of more distant wisps of nebulæ."

Circumstances prevented my securing a long-exposure photograph of the *Pleiades* in the winter of 1894, and since then I have not had an instrument for the purpose.

As in the case of the great nebula of ρ *Ophiuchi*, these nebulosities were known to me visually for many years before they were photographed. Indeed, there are other such nebulous regions elsewhere which I have seen in comet seeking, and I hope soon to be able to secure photographs of them, as in the case of the *Pleiades* and of ρ *Ophiuchi*. Some of these yet unphotographed nebulosities are, I believe, fully as remarkable as those just mentioned.

In the winter of 1898 Dr. H. C. Wilson, of Northfield, Minnesota, fully verified the exterior nebulosities of the *Pleiades*, and secured good photographs of them. In an endeavour to verify them he had secured traces as far back as 1894, with an exposure of $11^h\ 15^m$; but the photographs of 1898, with $5^h\ 35^m$ exposure, showed them distinctly. Dr. Wilson has given an account of these photographs, with reproductions, in *Popular Astronomy* for 1899 February.

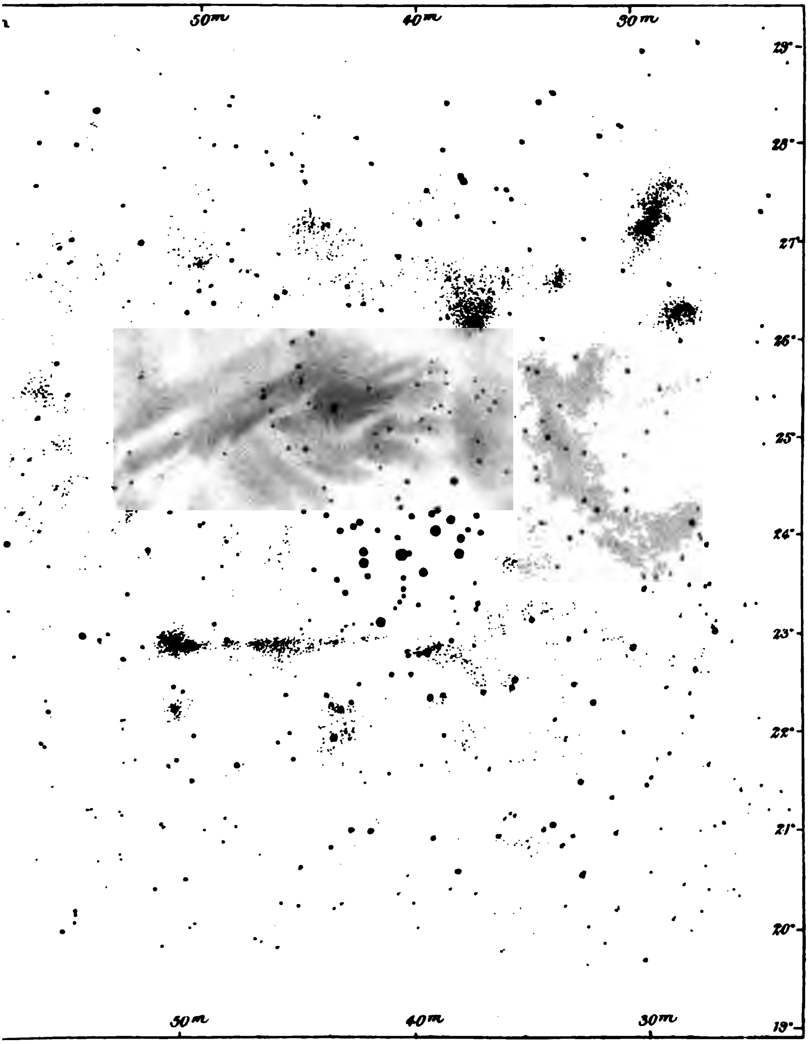
In the summer of 1898, while visiting Harvard College Observatory, I was shown, among many other interesting photographs, one of the *Pleiades* made at Arequipa, Peru, on 1897 October 29, by Professor Bailey with the 8-inch Bache telescope.

PHOTOGRAPH OF THE REGION OF THE PLEIADES,

SHOWING THE EXTERIOR NEBULOSITIES.

Made at the Arequipa, Peru, station of the Harvard College Observatory, with the 8-inch telescope, 1897 October 29. Exposure 300 minutes.

The fainter nebulosities have been brought out by successive intensifications from an original positive.



EXTERIOR NEBULOSITIES OF THE PLEIADES.

DRAWN BY E. CALVERT, FROM PHOTOGRAPHS

The exposure was 300 minutes. On this negative I could easily trace out these exterior nebulosities, though they were faint. Through the kindness of Professor E. C. Pickering I have been supplied with a glass positive of this picture, with permission to publish it (Plate 9).

This photograph readily verifies those made by me in 1893 and by Dr. Wilson in 1894 and 1898. Every detail has been perfectly and satisfactorily verified, leaving no question, in the mind of an unprejudiced person, of the existence of those singular nebulosities exterior to, but connected with, the *Pleiades*.*

One startling fact brought out by the study of these photographs is that the *Pleiades* and their involved nebulosities are but the central condensation of an enormous nebula, intricate in details, and covering at least 100 square degrees of the sky.

The great magnitude of this nebula or nebulosity appears almost beyond belief. Taken, however, in the light of other masses of nebulosity revealed by photography, such as those in *Monoceros*, in *Cygnus*, and in *Ophiuchus*, not to mention the great curved nebula stretching across a large portion of the constellation of *Orion*, it should not appear at all strange. Indeed, however strange it may appear is of little consequence, for it is an established fact that must be faced and accepted.

During the present summer I have taken advantage of a visit of Mr. E. Calvert, my brother-in-law, a skilled artist, to get him to make a careful drawing of these nebulosities from the various photographs, basing the work on the Harvard College photograph on account of its greater scale. The result is a very beautiful and accurate drawing in negative. This drawing I have forwarded with this paper, after having placed a system of coordinates around it by which the position of any feature of the nebula may be taken at sight for the epoch 1900 (Plate 10).

The drawing does not show the full extent of the nebulosities, and is therefore only a partial map of these remarkable features. The nebulosities extend for a considerable distance in all directions beyond what is shown on the drawing, which terminates rather abruptly. Especially does the nebulosity extend to the eastward much further than shown. The portion drawn covers from about $\alpha = 3^h\ 25^m$ to $\alpha = 4^h\ 0^m$, and from $\delta = +19°$ to $\delta = +29°$, extending thus over some ten degrees square.

It was not thought desirable to draw in the older nebulosities, as they are already so well known, and were burned out on the prints from which the drawing was made. The bright stars of the cluster, however, are shown for convenience in the study of the picture, and are inclosed in a faint circle inside of which all the previously known nebulosities are located.

The remarkable peculiarities of the nebula are strikingly shown in the drawing. It will be seen that the brightest portion

* On a recent visit to Dr. Max Wolf I was shown an excellent negative of the *Pleiades* in which the exterior nebulosities are distinctly traced. [Note added Feb. 1900].

(which ought to be easily photographed by such an instrument as the Crossley reflector at the Lick Observatory) is the centre of strongly marked details in

$$\alpha = 3^{h}\ 44^{m} \quad \delta = +25^{\circ}{\cdot}4.$$

This is at the 6^{m} star Piazzi iii. 170, which is Rad. 434, and whose position for 1860·0 is

$$\alpha = 3^{h}\ 41^{m}\ 54^{s}{\cdot}30 \quad \delta = +25^{\circ}\ 9'\ 15''{\cdot}3.$$

There is some delicate detail of a wispy nature in

$$\alpha = 3^{h}.34^{m} \text{ from } \delta = +21^{\circ}{\cdot}5 \text{ to } \delta = +24^{\circ}{\cdot}0.$$

Many of the details shown on this drawing will be fairly easy objects to photograph with the larger reflectors, whose scale will be big enough to show their individual peculiarities. Indeed, from what is already shown with the portrait lenses, I believe many of these details are far more interesting and peculiar than any involved in the cluster itself.

While on the subject of the *Pleiades*, I have lately, while measuring stars in the cluster, examined the inner nebulosities, and have been struck with their distinctness in the great telescope. The nebulosities in the region of *Merope* are perhaps the most striking. The following edge of the nebula of *Merope* which follows *Merope* some 5′, and which on the Henry Brothers chart extends from $3^{h}\ 39^{m}{\cdot}7$ to $3^{h}\ 40^{m}$, and from $\delta = +23^{\circ}\ 35'$ to $+23^{\circ}\ 40'$, is remarkably sharply defined, so much so under the best conditions that one could easily lay a micrometer wire along it to a second of arc. There are several long strips of nebulosity between this and *Merope*, which are very conspicuous objects. Even the original nebulosity discovered by Tempel, extending south-westerly from *Merope*, and which is specially suited for small telescopes, comes out very strong in the 40-inch. The small roundish nebula close to *Merope* which was found with the 36-inch in 1890, is a decidedly conspicuous object. Under the best conditions it seems somewhat irregular in outline.* The nebulosities about *Maia* are very easy, and strongly shown. The prong-like projection preceding from *Electra* is well seen, but rather faint and diffused. Some of the nebulosities about *Alcyone* could be made out, but this region is difficult from the radiance of *Alcyone* and its neighbouring stars.

I have now 120 nights' measures of the difference of declination of *Atlas* and *Pleione* for the study of temperature changes in the 40-inch object glass, and this work has frequently led me to examine the *Pleiades* and their involved nebulosities.

In conclusion, with reference to the photographs of the exterior nebulosities of the *Pleiades* made in 1893, I would refer to a previous paper of mine in *Monthly Notices*, vol. lvii. pp. 10–16, in which a photograph is reproduced in negative. For a com-

* With the 40-inch there is an excessively faint point of light on the edge of the nebulosity towards *Merope*.

parison of this with our present drawing, it must be looked at in a mirror, or must be supposed to be seen through the back of the paper, since it is reversed, or in the same condition with reference to orientation as the original negative looked at from the film side. The title of the above paper is "On the Comparison of Reflector and Portrait Lens Photographs."

That photograph has suffered in the reproduction, and does not show the exterior nebulosities as distinctly as it ought to.

On the photographs of the *Pleiades* made in 1893 December a star near *o Persei* is shown to be densely involved in nebulosity. It is 7′ south of, and 3′ following, *o Persei*, and is identified as DM $+31^\circ{\cdot}643$. The position for 1855·0 is

$$\alpha = 3^h\ 35^m\ 27^s{\cdot}6 \quad \delta = +31^\circ\ 42'{\cdot}2.$$

It is given as $8^m{\cdot}2$ in DM.

I have lately examined this star (which is reddish in colour) with the 40-inch, and it is surrounded for some distance with conspicuous nebulosity.

Yerkes Observatory, Williams Bay, Wisconsin:
1899 *November.*

On the Diameter of Ceres and Vesta. By E. E. Barnard.

During the oppositions of 1894 and 1895 a series of measures of the diameters of *Ceres* (1), *Pallas* (2), *Juno* (3), and *Vesta* (4), were made with the 36-inch of the Lick Observatory (*M.N.* vol. lvi. pp. 55–63).

The diameters thus obtained were (reduced to Δ 2·7673):—

Ceres	0″·389	23 nights
Pallas	0·244	5 ,,
Juno	0·095 ±	4 ,,
Vesta	0·195	18 ,,

I have endeavoured to redetermine these diameters here with the large telescope, but the conditions have not been favourable for the use of sufficiently high power for the purpose. A few nights' measures, however, were obtained of *Ceres* and *Vesta*. These, though not considered so satisfactory as the measures which I secured in 1894 and 1895, verify the diameters then obtained, and show that they can be relied upon as being as accurate as can be secured by the work of one observer.

The following are the only measures it has been possible to secure with the 40-inch.

Ceres (1).

	Apparent.	Δ 2·7673.
	$''$	$''$
1897 Nov. 22	0·64	0·42
„ 23	0·55	0·36
Dec. 26	0·57	0·34
„ 27	0·55	0·33
1898 Jan. 2	0·51	0·31
		0·352

Vesta (4).

	Apparent.	Δ 2·7673.
	$''$	$''$
1899 Sept. 26	0·38	0·21
Oct. 7	0·32	0·17
„ 8	0·26	0·14
		0·175

The observations were difficult in each case.

These values when combined with the previous measures will not sensibly change them, and the first series should have the greatest weight. If we make this combination, weighting, by number of observations alone, we should have: Diameter of *Ceres*, $0''{\cdot}383$; diameter of *Vesta*, $0''{\cdot}192$, at distance 2·7673.

Yerkes Observatory, Williams Bay, Wisconsin:
1899 *October* 26.

Observations of the Leonids, 1899. By C. Michie Smith, Director of the Kodaikanal and Madras Observatories.

A careful watch for *Leonids* was carried out from the Kodaikanal Observatory on the morning of November 14 and on the three following nights. The approximate position of the Observatory is Lat. 10° 14′ N., Long. $5^h\ 10^m$ E.; height above sea level 7,700 feet. The following observations were made by the director and the first assistant, Mr. K. V. Sivarama Aiyar. Observations were also made by others of the assistants, but it has not been considered necessary to give these, as they do not cover any extra time. The time used is Madras mean time.

Date.	Count begins.	Count ends.	No. of Leonids seen.	Remarks.
	h m	h m		
Nov. 13	15 52	16 07	2	
	16 10	16 25	nil	
	16 25	17 10	3	1 equal to Venus.

Date.	Count begins. h m	Count ends. h m	No. of Leonids seen.	Remarks.
Nov. 14	13 20	14 00	4	
	14 00	15 00	4	
	15 00	16 00	4	15 of these were of the first magnitude.
	16 00	16 30	6	
	16 30	17 05	7	
	Watch ended at $17^h\ 15^m$ in advancing dawn.			
15	12 10	13 00	4	
	13 00	14 00	3	
	14 00	15 00	7	21 of the first magnitude.
	15 00	16 00	7	
	16 00	17 00	15	
	17 00	17 09	9	
16	12 00	14 00	1	
	14 00	15 00	Not observed	
	15 00	16 00	6	
	16 00	17 00	3	

The weather throughout was fine, with only very light passing clouds or occasional thin films of mist driving over the Observatory.

All records in this and the following lists were made within the area of Professor Pickering's map.

At Madras, Professor R. Ll. Jones, assisted by S. Solomon Pillai and S. Sitarama Aiyar, observed in nearly equally favourable weather, with the following results :—

Date.	Count begins. h m	Count ends. h m	No. of Leonids seen.	Remarks.
Nov. 13	10 00	15 00	nil	Fine and clear.
	15 00	16 00	3	
	16 00	17 00	5	
14	12 00	13 00	nil	Quite clear after $13^h\ 30^m$.
	13 00	14 00	1	
	14 00	15 00	nil	
	15 00	16 00	10	Moon set $15^h\ 45^m$.
	16 00	17 00	16	
	17 00	17 13	1	

Date.	Count begins.	Count ends.	No. of Leonids seen.	Remarks.
	h m	h m		
Nov. 15	12 20	14 15	nil	Passing clouds.
	14 15	15 00	3	
	15 00	16 00	8	Moon set about $16^h\ 35^m$.
	16 00	17 00	12	
16	–	15 08	nil	
	15 08	16 00	3	
	16 00	17 00	1	
17	15 00	17 00	2	Cloudy till 15^h.

Of the other counts that have been forwarded to me, the most interesting is a series made by the Rev. Oswald O. Williams, B.Sc. (London), L.S.A., at the Mission House, Karimganj, Assam. This station is thirty-four miles due east of Sylhet, and the time used was local mean time, which is 49^m fast of Madras mean time. The following is a summary of the results :—

Date.	Count begins.	Count ends.	No. of Leonids seen.	Remarks.
	h m	h m		
Nov. 13	13 30	14 00	2	Clear sky.
	14 00	15 00	nil	
	15 00	16 00	12	
	16 00	16 30	8	
	16 30	16 45	4	Zodiacal light magnificent.
	16 45	17 00	4	
14	13 30	–	1	Sky perfectly clear.
		After Moon set.		
	16 00	16 15	11	
	16 15	16 35	Several seen but not counted.	
	16 35	16 45	12	
	16 45	17 00	24	2 of first magnitude.
	17 00	17 08	12	
	17 08	17 15	10	
		Dawn.		
	17 15	17 18	4	
	17 18	17 22	5	
	17 33	17 30	2	
15	Very foggy. No observations.			
16	Went out thrice but saw no meteors, much moonlight.			

Kodaikanal Observatory.

Note on the Unpublished Observations made at the Radcliffe Observatory, Oxford, between the years 1774 *and* 1838; *with some Results for the year* 1774. By Arthur A. Rambaut, M.A., D.Sc., Radcliffe Observer.

The debt which Astronomy owes to the enlightened liberality of the University of Oxford and to the zeal of its two illustrious Professors, Hornsby and Robertson, who devoted a large proportion of their lives to the editing of the remarkable series of observations made by Bradley at the Royal Observatory, Greenwich, is well known to all lovers of Astronomy of precision.

At the Radcliffe Observatory were compiled, and at the University Press were printed, the two large tomes entitled *Astronomical Observations made at the Royal Observatory, Greenwich, from the year* 1750 *to the year* 1762—the first volume edited by Hornsby, in 1798, the second by his successor, Robertson, in 1805. On this foundation was built up the superb structure of Bessel's *Fundamenta Astronomiæ*, and, at a much later date, the valuable system of star places which we owe to Auwers' *Neue Reduction der Bradley'schen Beobachtungen.*

In the opening paragraph of his preface to the *Fundamenta* Bessel pays a just tribute of admiration to the diligence and industry of these remarkable men, and all who have ever had occasion to make use of Bradley's observations will endorse Bessel's words. But while the names of Hornsby and Robertson must ever be associated with that of Bradley in this work, many astronomers are, I think, unaware that the admiration which these two eminent men felt for their illustrious predecessor—for Bradley, too, had been Professor of Astronomy at Oxford—was not confined to a minute and careful study of his work, but was exhibited in a still more practical form by carrying on and enormously extending his observations with the instruments which the liberality of the Trustees of Dr. Radcliffe's will had placed at their disposal.

When the Radcliffe Observatory was built (1771–1773), it was equipped with instruments by Bird similar, but in some important respects superior, to those which he had previously made for Bradley at Greenwich. These consisted of two quadrants of 8-feet radius, a transit instrument of the same focal length, and a zenith sector of 12 feet.

With these instruments Hornsby and his successors, Robertson and Rigaud, maintained a systematic and regular series of observations for 65 years, from 1774 to 1838, interrupted only, owing to Hornsby's failing health, between the years 1803 and 1810, when he died. These observations were all regularly and methodically copied into large folio books, in a form exactly similar to Hornsby's and Robertson's printed edition of Bradley's obser-

vations; but while the results of their zealous labour in editing the latter have become the ground-work of accurate astronomy, their own observations, amounting to the number of about 130,000 transits and more than 60,000 zenith distances, have been allowed to sink into oblivion.

Of the importance attached to his observations by Hornsby himself, and of the high opinion he held of the excellence of his instruments, there can be no doubt from the various statements in his published and MS. writings. More than half a century after their erection Rigaud writes that the quadrant finished in 1772 was probably the finest that the maker ever executed.

With the present staff of the Radcliffe Observatory fully occupied, as they are, with their other astronomical and meteorological duties, I could not hope to reduce and publish this enormous mass of valuable observations which have been lying idle on our library shelves. I have, however, reduced all the observations of stars and the Sun made in the year 1774 as an example of the material that is available, although indeed it is hardly a fair specimen of the whole, since 1774 was the first year of Hornsby's work, when the instruments were still unfamiliar, and some precautions afterwards adopted had not yet been thought of. The reduction of the observations of this year had, however, been commenced by my predecessor, and it was only as the work advanced that the defects of this year's observations, as compared with those of later years, became apparent.

The results have, however, convinced me that these observations are of a very high degree of accuracy, as may be judged from the specimens published in this paper; and I trust that when the facts are made known, means will be found for reducing and rendering available for practical purposes the rich mines of astronomical wealth which have remained so long unworked.

The Transit Instrument.

The transit instrument, with which the following observations were made, continued in use at the Observatory till the year 1842, when it was remodelled by Simms.

In this process, although the instrument had been in use for sixty-nine years, several of the principal parts of it were found so good that they were retained in the new construction.

An account of this instrument is given by Manuel Johnson in the first volume of the Radcliffe Observations. The object glass was a particularly good achromatic, made by Peter Dollond; its focal length was 8 feet and its diameter 4 inches, the whole of which was always employed except for observations of the Sun and of the adjusting mark. The tube of the telescope was composed of four cylindrical pieces attached to a cubical centre-piece. The horizontal axis was 3 feet 10 inches long. The pivots were 1·6 inches in diameter and 2·5 inches

long, of which 0·6 inch only rested on the Y's; the remaining portion was left for receiving the index of the setting-circle and the rods for connecting the axis with the counterpoises. The counterpoising apparatus consisted of upright bars of iron 18 inches long, cased in mahogany, firmly fixed to the tops of the piers, terminating at their upper ends in knife edges, which formed the fulcra of wooden beams, from one extremity of which hung the counterpoises, and from the other, flat rods of wood with triangular bearings at the bottom to receive the pivots. The inclination of the axis was adjusted by means of a spirit level, and the collimation and azimuth by means of a mark fixed on the north wall of Worcester College at a distance of about 682 yards to the south of the transit instrument. Whenever the line of collimation appeared to Dr. Hornsby to be sensibly in error, he seems to have adjusted it to zero; and in a similar way the error of inclination was eliminated by the use of the spirit level.

Dr. Hornsby's minute watchfulness as to the adjustments of his transit instrument is shown by a number of entries in his journal both for 1774 and later years. Thus under the date 1778 July 29 he says: "Immediately before the observation of *Arcturus* I examined the Instrument by the Level and found the Eastern End of the Axis too high by 3″. The alteration of the Instrument has generally been this way, and I attribute it to the weight of the Center part of the Observatory, which, though at the distance of several feet from the western Pier, seems to affect that Pier more than the other, which is about 5 feet further distant. It is very rare to perceive any alteration in the direction of the Instrument or the Line of Collimation."

Here he refers to the central tower, 100 feet high, which was then being erected. On 1779 March 27 he writes: "The Axis of the Instrument was found truly horizontal. Since the Center part of the Building has been finished, and the Ground has received its full weight, the western end of the Axis has ceased to sink."

Dr. Hornsby, too, seems to have been very careful to take precautions against the disturbing effect of the solar heat on the instruments before and during his observations of the Sun. We have, indeed, no explicit statement that he shielded his transit instrument from the Sun's rays, but we have the indirect evidence afforded by notes of exceptions to such a habit. Thus on 1776 January 29 we have a note to the transit of the Sun's first limb: "Did not shade y^{e} Axis." Also on 1779 March 25: "N.B. The Sun had shone upon the western end of the Axis, before the meridional obsn. of the Sun this day was made, but the Axis had been shaded near half an hour." Again, on 1779 October 21 he writes: "I suspect that the Sun began to shine upon a small part towards the middle of the west end of the Axis, when Mercury had passed the second wire."

From these notes it is only reasonable to conclude that his usual custom was to protect the instrument against the disturbing

effect of the Sun's direct radiation. In the case of the quadrants, however, we have a note under 1774 May 31 to the effect: "Applied a Strip of Mahogany to the Pier to prevent the Sun from shining on the Quadrant during the time of observation at noon;" in which position it still remains.

The Sidereal Clock.

We have no explicit statement as to the clock which was used by Hornsby for his transit observations, but many considerations lead me to conclude, with a high degree of certainty, that it was no other than the old clock, by John Shelton, which stands to the present day in the old transit-room in the east wing of the Observatory building. This clock is furnished with a gridiron compensating pendulum of brass and steel, with a dead-beat escapement, flint pallets, and maintaining power. It is of beautiful workmanship, and still performs very well. The character of its performance 126 years ago may be judged from the table of clock rates for the year 1774 as given on pp. 271–2.

Mural Quadrants.

The two mural quadrants were made by John Bird, between the years 1771 and 1774, on the lines of the similar instrument constructed for Bradley at Greenwich about twenty-one years previously. These two instruments were in every particular alike in design, and were mounted on the north and south faces of the same pier in the extreme east of the Observatory. In each case the object glass was a Dollond of 3 inches; but the aperture was limited to 2·75 inches by the elliptic reflector placed in front of it for illuminating the field. The radius of each quadrant was 8 feet, and, as was usual in Bird's instruments, the arcs were furnished with two sets of divisions; the inner set to degrees and twelfths of a degree, the outer into the ninety-sixths of a right angle, each ninety-sixth part being again divided into sixteen. Each of these arcs was read by a vernier, which was further subdivided by a micrometer screw attached to the telescope as in Bradley's instrument.

In these, as with other quadrants by Bird, the divisions of the 96 arc seem to be much superior to those of the 90 arc; and for this reason in the observations of 1774, though both arcs were usually read, we have only employed those of the 96 arc.

It is not necessary to give here a detailed description of these instruments, as the description contained in Bird's paper "On the Method of constructing Mural Quadrants," published in 1768 by order of the Commissioners of Longitude, is in every respect applicable to them, and the illustrations of that paper might have been made from the Oxford quadrants. These quadrants

still stand in their original positions at the Radcliffe Observatory, and though certain small alterations have from time to time been made in them—such as an eyepiece micrometer to the south quadrant, which seems to have been supplied by Edward Troughton—they are substantially the same instruments with which Hornsby worked.

The error of the arc of each quadrant was very carefully determined by Hornsby by the method used by Bradley for this purpose, and described on p. 24 of Bird's paper referred to above. From a careful investigation he concludes that the 96 arc of the north quadrant is $13''$ too great, and the 96 arc of the south quadrant $1''\cdot 5$ too little. Corrections for these errors have been applied to all the observations given below.

Reduction of the Observations.

Right Ascensions.—In reducing the observations of R.A. I have taken Bessel's formula, viz. :—

$$a = t + \tau + m + n \tan\delta + c \sec\delta$$

where a denotes the right ascension, t the clock time of transit corrected for diurnal aberration, and the other symbols have the same signification as in Bessel's *Fundamenta*.

In view of the care which Hornsby devoted to the adjustment of the collimation, and having regard to the stability of the instrument, I have in this preliminary reduction felt myself justified in neglecting the last term, and thus reducing the equation to the form

$$a = t + p + n \tan\delta$$

an expression which very much simplifies the computations.

On three dates, however, when Dr. Hornsby found the exceptional collimation error of $0^s\cdot 08$, we have applied a correction for this error in the usual way before deducing the constants p and n.

For deducing the values of p and n I have limited myself to the transits of the thirty-two stars of Maskelyne's list selected by Professor Newcomb on p. 52 of Appendix III. to the *Washington Observations* for 1870, and the transits of *Polaris* and *δ Ursæ Minoris*. The mean places of these stars for 1774·0 were taken from Newcomb's "Catalogue of 1098 Standard and Zodiacal Stars," their apparent places for the dates of observation being reduced by the aid of "Tabulæ Quantitatum Besselianarum pro annis 1750 ad 1840 computatæ." In deducing the tabular places of *Sirius* and *Procyon* Professor Auwers' corrections for orbital motion have been applied.

The agreement *inter se* of the separate values of p and n affords a very good criterion of the character of the observations

on any day. The following two specimens are selected, not as being particularly good, but because on each date a large number of clock stars were observed. We have on March 16 :—

	n	p
	s	s
α Tauri	−0·320	+25·18
α Aurigæ	·315	25·28
β Orionis	·321	25·18
β Tauri	·314	25·28
α Orionis	·325	25·10
α Canis Majoris	·312	25·32
δ Ursæ Min. S.P.	—	25·24
α Canis Minoris	·316	25·25
β Geminorum	·314	25·28
Means	−0·317	+25·23

and on August 6–7 :—

	s	s
α Tauri	+0·113	+12·01
α Aurigæ	·110	11·90
β Orionis	·109	11·87
β Tauri	·110	11·91
α Orionis	·111	11·96
α Canis Majoris	·113	11·99
α Canis Minoris	·114	12·04
β Geminorum	·111	11·93
α Hydræ	·109	11·88
α Leonis	·117	12·11
β Leonis	·110	11·90
Polaris S.P.	—	11·94
α Virginis	·107	11·82
α Boötis	·107	11·83
α² Libræ	·111	11·94
α Coronæ	·106	11·79
α Serpentis	·109	11·89
α Scorpii	+0·115	+12·04
Means	+0·111	+11·93

and in general the agreement is so good as to justify a high degree of confidence in the precision of the observations.

It should be remarked that the value of n in the first example is exceptionally large. The largest value during the year was $0^s·331$. In general it was kept very much smaller.

The following table of the clock rate for each date of observation throughout the year shows very clearly the excellent character of Hornsby's clock :—

Daily Rates of the Sidereal Clock at the Radcliffe Observatory, Oxford, in the Year 1774.

Day.	Daily Rate. s	Day.	Daily Rate. s	Day.	Daily Rate. s	Day.	Daily Rate. s
Jan. 23	+0·21	Mar. 24	+0·76	May 22	+0·60	Aug. 2	+0·95
24	+0·27	25	+0·76	23	+0·60	3	+0·96
25	+0·38	26	+0·67	27	+0·71	4	+0·95
26	+0·55	27	+0·60	29	+0·71	5	+0·93
28	+0·30	28	+0·58	June 1	+0·71	6	+0·90
29	+0·50	29	+0·58	2	+0·71	7	+0·92
30	+0·71	30	+0·58	4	+0·79	8	+0·94
31	+0·60	31	+0·61	7	+0·82	9	+0·94
Feb. 2	+0·66	Apr. 1	+0·57	13	+0·78	10	+0·90
5	+0·60	3	+0·57	16	+0·74	11	+0·94
7	+0·63	4	+0·59	18	+0·62	12	+0·94
8	+0·67	5	+0·64	19	+0·64	13	+0·90
15	+0·67	6	+0·54	26	+0·77	14	+0·95
16	+0·67	7–8	+0·58	28	+0·75	Pendulum	adjusted
17	+0·69	9	+0·62	July 3	+0·85	15	−0·05
18	+0·67	10	+0·63	4	+0·81	17	0·00
20	+0·66	12	+0·72	9	+0·73	18	+0·16
21	+0·53	13	+0·72	11	+0·80	19	+0·05
22	+0·48	18	+0·70	14	+0·84	20	+0·05
23	+0·53	20	+0·56	15	+0·84	21	+0·13
24	+0·56	21	+0·63	16	+0·87	23	+0·25
25	+0·59	23	+0·88	17	+0·90	24	+0·25
26	+0·60	26	+0·70	20	+0·75	25	+0·25
27	+0·63	27	+0·75	21	+0·75	26	+0·18
28	+0·67	May 1	+0·75	22	+0·75	27	+0·05
Mar. 1	+0·69	3	+0·64	23	+0·79	29	0·00
11	+0·65	5	+0·67	24	+0·73	New clock	weight
13	+0·63	8	+0·76	25	+0·64	Sept. 4	−0·05
14	+0·62	9	+0·76	26	+0·69	5	−0·05
15	+0·64	10	+0·73	27	+0·74	7	+0·10
16	+0·63	13	+0·81	28	+0·72	8	+0·21
18	+0·53	14	+0·77	30	+0·80	9	+0·18
19	+0·52	15	+0·66	31	+0·88	10	+0·23
20	+0·59	16	+0·72	Aug. 1	+0·89	11	+0·23

Day.	Daily Rate.	Day.	Daily Rate.	Day.	Daily Rate.	Day.	Daily Rate.
	s		s		s		s
Sept. 12	+0·06	Oct. 8	+0·20	Nov. 1	0·00	Nov. 29	−0·17
13	+0·07	9	+0·20	9	−0·16	30	−0·06
15	+0·12	10	+0·18	10	−0·13	Dec. 1	−0·03
16	+0·10	12	+0·24	13	−0·05	5	−0·12
19	0·00	14	+0·20	15	+0·14	6	−0·03
20	−0·02	15	+0·14	16	+0·09	7	+0·02
21	−0·06	16	+0·14	17	+0·16	8	+0·05
27	−0·06	20	+0·21	18	+0·18	9	0·00
29	−0·01	21	+0·17	19	+0·19	11	−0·05
30	+0·05	24	+0·06	20	+0·30	13	+0·09
Oct. 1	+0·08	25	+0·13	21	+0·26	15	+0·10
2	+0·15	26	+0·21	23	+0·22	22	+0·01
3	+0·25	27	+0·27	24	+0·08	24	+0·07
4	+0·28	28	+0·30	26	0·00	25	+0·14
5	+0·23	29	+0·27	27	−0·07	30	+0·02
6	+0·23	31	+0·26	Barom. fell 0·75 in.		31	0·00
7	+0·23	Pallets oiled		28	−0·28		

Dr. Hornsby seems to have made a point of observing the Sun and planets on every possible occasion. The care which he took to shield his instrument from the effect of the Sun's heat during the observation has doubtless contributed largely to the remarkable consistency of the results for the Sun as exhibited in the following table :—

Observed Horizontal and Vertical Diameters, and R.A. and Decl. of the Sun, 1774, compared with Tabular Quantities.

Day, 1774.		Duration of Transit of Diameter. Tabular *minus* Observed.	Number of Wires. Limb I.	Limb II.	Vertical Diameter. Tabular *minus* Observed.	R.A. Tabular *minus* Observed.	Decl. Tabular *minus* Observed.
		s			″	s	″
Jan.	23	−0·11	2	3	−4·57	+0·10	+2·25
	25	−0·05	3	3	−2·94	+0·25	−0·14
	30	+0·03	2	4	−5·80	+0·10	+5·54
	31	−0·11	3	3	−3·82	+0·21	+1·75
Feb.	7	0·00	2	2	−3·05	+0·20	+5·59
	18	+0·01	1	2	...	0·00	...
	20	−0·22	1	2	−5·16	+0·23	+0·84
	26	...	...	...	...	−0·07	−0·32
	27	−0·38	3	2	−4·45	+0·20	−1·43
Mar.	1	−0·14	2	1	−9·02(::)	+0·25	−1·20

Day, 1774.		Duration of Transit of Diameter. Tabular *minus* Observed.	Number of Wires. Limb I.	Limb II.	Vertical Diameter. Tabular *minus* Observed.	R.A. Tabular *minus* Observed.	Decl. Tabular *minus* Observed.
		s			"	s	"
Mar.	12	−0·36	1	3	−5·08(:)	+0·09	+0·33
	13	−0·32	3	3	−2·20	0·00	−0·09
	14	−0·64	1	3	−4·54	+0·16	−1·30
	15	+0·03	3	3	−1·72	+0·16	+2·57
	17	−0·12	2	3	+1·77(:)	−0·13	+1·03
	18	+0·06	3	3	−1·50	+0·10	−0·93
	25	−0·40	1	2	+1·74	+0·35	−3·36
	26	−0·09	1	2	...	−0·04	+2·80
	27	−0·12	2	3	+0·59	+0·04	−1·47
	28	−0·17	2	4	−2·01	+0·02	+0·86
	29	−0·06	3	3	−2·86	+0·07	+4·54
	30	−0·04	3	3	−1·24	+0·36	+2·35
	31	−0·16	3	3	−3·58	+0·01	−2·79
Apr.	1	−0·29	2	3	−2·50	+0·18	+2·03
	10	+0·22	3	2	−5·22	+0·17	+3·16
	12	+0·01	1	4	...	(−0·02)	+2·38
	13	−0·14	2	3	−0·26	+0·20	+1·73
	21	+0·25	1	3	−0·81	+0·36	−2·55
	24	+0·16	1	1	...	+0·22	−2·84
	26	−0·01	1	2	−0·26(:)	+0·27	+2·52
May	1	−0·12	2	4	...	+0·11	+1·94
	14	+0·16	3	2	...	+0·29	+1·70
	15	+0·04	4	3	...	+0·05	+0·13
	16	−0·12	4	4	...	+0·14	−0·24
	18	...	...	...	...	...	+0·78
	27	...	...	...	...	...	−0·12
June	1	−0·01	2	1	...	−0·02	+0·24
	2	+0·26	1	4	...	+0·07	−4·23
	4	+0·04	4	4	...	+0·12	−2·28
	7	−0·18	1	2	...	+0·01	+0·36
	11	...	...	...	...	(+0·29)	−0·50
	12	+0·10	2	4	...	+0·26	+0·61
	13	−0·23	4	3	...	−0·01	+0·03
	16	−0·15	1	3	...	+0·02	−1·70
	18	+0·04	3	2	...	+0·09	+4·09

Apr. 12, June 11. Clock-errors doubtful.

Day, 1774.		Duration of Transit of Diameter. Tabular *minus* Observed.	Number of Wires. Limb I.	Limb II.	Vertical Diameter. Tabular *minus* Observed.	R.A. Tabular *minus* Observed.	Decl. Tabular *minus* Observed.
		s			"	s	"
June	19	+0·07	3	3	...	+0·06	−0·01
	29	−0·05	2	3	...	+0·33	+0·70
	30	−0·10	1	3	...	(+0·33)	−3·07
July	4	−0·18	3	3	...	+0·09	−0·36
	8	+0·13	4	4	...	+0·13	−0·87
	9	0·00	4	3	...	+0·10	+0·61
	11	+0·06	4	2	...	+0·07	−0·22
	16	+0·03	2	3	...	+0·33	+4·15
	23	−0·14	3	4	...	+0·25	...
	24	−0·01	4	4	...	+0·16	...
	25	...	...	...	...	+0·14	+2·97
	26	+0·15	4	4	...	+0·29	+5·03
	28	−0·19	4	4	...	+0·22	+1·88
	30	+0·09	1	4	...	0·00	+1·86
Aug.	1	+0·04	2	3	...	+0·11	−0·45
	2	−0·20	4	3	...	+0·24	−4·25
	3	−0·45	3	3	...	+0·13	+3·25
	5	−0·22	4	4	...	+0·32	+1·13
	7	−0·12	4	4	...	+0·09	−1·55
	8	−0·02	3	4	...	+0·12	−1·90
	9	0·00	2	2	...	+0·16	+2·67
	10	−0·11	3	4	...	+0·01	+1·16
	11	+0·04	2	4	...	+0·19	−3·37
	12	+0·14	4	2	...	+0·02	+0·27
	15	−0·05	2	2	...	+0·07	...
	18	+0·08	2	3	−4·03	+0·14	+0·49
	19	+0·06	2	3	...	−0·21	+2·05
	21	−0·06	3	3	...	+0·09	−2·07
	22	+0·18	2	3	...	−0·09	−5·04
	23	...	...	...	...	+0·10	−0·18
	24	+0·03	2	3	−0·92	+0·48	+1·57
	25	+0·13	3	3	−2·29	+0·09	−1·63
	26	−0·09	3	3	...	+0·10	−3·79
	29	−0·17	2	3	−6·28	+0·26	−1·90
Sept.	3	−0·16	4	4	...	0·00	−2·92

June 30. Clock-error doubtful.

Day, 1774.		Duration of Transit of Diameter. Tabular *minus* Observed.	Number of Wires. Limb I.	Limb II.	Vertical Diameter. Tabular *minus* Observed.	R.A. Tabular *minus* Observed.	Decl. Tabular *minus* Observed.
		s			"	s	"
Sept.	5	...	...	...	...	+0·23	−1·87
	7	−0·02	3	2	...	−0·03	+0·81
	8	−0·18	3	2	−8·36	+0·01	−0·97
	9	−0·12	3	1(:)	−7·06	0·00	−4·46
	11	−0·42	1	3	−5·92	+0·22	−0·62
	13	−0·09	3	4	...	+0·22	−0·74
	14	+0·18	2	2	...	+0·07	−3·59
	15	−0·10	3	3	−3·74	+0·03	−3·00
	16	+0·19	3	3	−1·94	−0·10	−3·71
	23	+0·10	3	3	−4·47	(−0·14)	−0·20
	27	−0·21	2	3	−4·97	−0·03	+2·58
Oct.	2	...	...	...	...	+0·18	...
	3	+0·10	3	3	−2·22(:)	+0·11	−0·53
	4	−0·09	3	3	−5·11	+0·06	−0·90
	5	+0·14	2	2	−4·66	+0·27	+0·31
	6	+0·20	3	3	...	−0·04	...
	8	+0·07	3	3	−9·03	+0·30	+0·28
	9	0·00	3	1	...	+0·12	−3·78
	10	...	...	...	...	(+0·07)	−3·83
	11	+0·26	3	3	...	+0·20	+2·24
	12	−0·03	3	3	−3·90	+0·25	−1·61
	15	+0·09	3	3	−4·92	+0·03	−1·92
	16	−0·07	3	3	−6·19	+0·14	−0·15
	20	−0·12	2	3	−5·64	−0·05	−4·03
	24	−0·09	4	5	...	+0·02	−2·23
	25	−0·11	4	5	...	+0·11	−3·39
	26	−0·02	3	3	−4·75	−0·12	−3·79
	27	−0·03	3	3	−5·91	−0·04	−1·00
	28	−0·20	2	2	...	+0·11	−1·00
Nov.	10	−0·07	4	5	...	−0·02	−3·67
	12	...	...	...	...	+0·35	...
	13	−0·05	2	4	...	+0·14	−2·28
	16	...	...	...	...	+0·23	+2·55
	18	−0·06	3	3	−3·45	0·00	−1·70
	19	−0·10	3	3	−4·90	+0·02	−1·50

Sept. 23. Clock-error doubtful.

Day, 1774.		Duration of Transit of Diameter. Tabular *minus* Observed.	Number of Wires. Limb I.	Limb II.	Vertical Diameter. Tabular *minus* Observed.	R.A. Tabular *minus* Observed.	Decl. Tabular *minus* Observed.
		s			"	s	"
Nov.	20	+0·14	3	4	+0·02	+0·01	−1·21
	24	−0·20	3	3	−0·31	+0·14	−2·84
	29	+0·19	3	3	+2·48	+0·04	−2·08
	30	−0·06	3	3	−4·91	+0·16	−3·21
Dec.	1	−0·16	3	3	−5·36	+0·17	−4·08
	7	−0·20	3	4	−6·55	+0·16	−4·26
	13	+0·15	2	3	−2·85	+0·05	−0·88
	15	−0·40	1	3	−1·41	+0·14	−0·70
	22	−0·09	3	3	−8·14	+0·13	−1·82
	24	+0·10	2	4	...	+0·10	−2·68
Mean Errors for the Year		−0·042	...	...	−3·68	+0·118	−0·43

The times occupied by the transits of the Sun's diameter, and its vertical diameter, and the R.A. and Decl. of the Sun have been compared with the values of the same quantities as deduced from Newcomb's Tables. In computing the former the mean horizontal parallax of the Sun has been taken as 8″·80, and for its mean semi-diameter Professor Auwers' value of 16′ 1″·18 has been adopted. The values of the semi-diameter used to reduce observations of only one limb have been formed as explained in the *Radcliffe Observations*, 1890–91, p. xv, reading Newcomb's Tables for *Nautical Almanac.*

The general agreement throughout the year of the tabular and observed right ascensions of the Sun's centre is, I think, very remarkable, the mean difference for the year—when a few observations are neglected for which the clock-error was doubtful, or which were marked as unsatisfactory by Dr. Hornsby—being only $0^s \cdot 118$. The symbols which Dr. Hornsby adopted for denoting various degrees of dissatisfaction, consisting of from two to six dots enclosed in brackets, are reproduced in the above table.

Declinations.—In determining the error of the line of collimation of the south quadrant I have relied on the declinations of the same list of thirty-two stars as was used for the clock-error. As was customary in his time, Dr. Hornsby frequently adjusted his instrument with great care by means of the screw provided for that purpose, so that the plumb-line should bisect two minute dots, one near the centre, and one near the zero of the graduations (cf. Bird's Paper). To determine the error of the line of collimation, therefore, we have to compare the declination, or zenith distance, of the standard stars, as observed

with the quadrant, with their computed values, and the mean of the differences so obtained is the "error of the line of collimation."

No complete investigation of the effect of temperature on either of the quadrants has yet been made. In the case of the north quadrant, the observations of the year 1774 are too few for a satisfactory examination of the question; and any such examination must be postponed till the observations of subsequent years are available for discussion. For the south quadrant, however, I have plotted down as ordinates the separate results in declination for a number of stars which were frequently observed, the abscissæ representing the temperatures; but I have been unable in any case to recognise a relation between the two, and am convinced that the effect of temperature, if it is sensible at all, must be very slight indeed.

The refractions have been computed as in the Radcliffe volumes for recent years. In the calculation of the refraction, we have taken Hornsby's readings of the internal and external thermometers without correction, but the barometer has been affected by a correction of −0·037 inch, as adopted by the late Mr. Stone from a memorandum found among Dr. Hornsby's papers. Dr. Hornsby seems to have been particularly careful in reading his barometer and thermometers.

The Probable Error of the Results.

In the *Fundamenta Astronomiæ* Bessel computes the mean error in R.A. and Decl. of Bradley's observations. From 300 observations of the stars *α Tauri*, *α Canis Majoris*, *α Canis Minoris*, *α Boötis*, and *α Aquilæ*, he finds the mean error of a single observation to be $\pm 1''\cdot45$; and from 300 observations of *α Canis Majoris* and *α*, *β*, and *γ Aquilæ*, he finds as the mean error of an observation in right ascension $\pm 0^s\cdot2114$. With a view to instituting as direct a comparison as possible between Hornsby's and Bradley's observations, with regard to their freedom from accidental errors, I have computed the mean error from such observations of the same groups of stars as Hornsby obtained in the year 1774. In the first group we have 158 observations of the declinations of the six stars composing it, and the mean error computed, as in Bessel's *Fundamenta*, is $\pm 1''\cdot87$. This seems to show that Dr. Hornsby's observations of declination in the year 1774 were not so good as Bradley's were. The difference, however, is on the whole not so marked as this mean error would seem to indicate, for this larger value is to a great extent due to irregularities in the observations of *Sirius*. The observations of some of the other stars of this group are considerably above Bradley's average of consistency. Thus the mean error computed from the thirty-three observations of *Arcturus* amounts to only $\pm 0''\cdot80$. The probable error of an

observation in declination computed in the usual way from the 158 observations of these six stars is $\pm 1''\cdot 27$. In right ascension Hornsby's observations for this year, as judged by their mean error, are considerably more trustworthy than those of Bradley. From 114 observations of the four stars selected by Bessel we find the mean error of an observation in right ascension to be $\pm 0^s\cdot 0798$, or, if all are reduced to the equator by the factor cos δ, $\pm 0^s\cdot 0785$; while the probable error of a single observation in right ascension amounts to only $\pm 0^s\cdot 053$. The observations of the Sun are also of a high order of accuracy. In computing the probable errors of the observed R.A. and Decl. of the Sun I have compared the observed places with the places computed from Newcomb's Tables. The differences are given on pp. 272 to 276. The mean difference for the year as given at the end of the table is taken as a constant systematic correction to the tables, and being subtracted from each individual difference gives the residuals from which the probable errors are computed. In this way I find the probable error of an observation of the Sun's R.A. is equal to $\pm 0^s\cdot 0834$, while in declination I find the probable error $\pm 1''\cdot 62$.

Conclusion.

In order to form an approximate idea of the number of observations contained in the unpublished journals in the period (1774–1838) I have had the number of folio pages counted for each year, and the actual number of observations counted for the years 1774, 1775, 1776, 1785, 1791, 1800, 1814, 1825, and 1836, as shown in the accompanying Tables A and B. It should be remarked that in Table A the numbers of observations of the Sun, Moon, and planets, which are given in separate columns, are included in those contained in the second and third columns.

Table A.

Numbers of Observations in Several Years.

Year.	Counted Number of Transits.	Counted Number of Zen. Dist.	Sun. T.	Sun. Z.D.	Moon. T.	Moon. Z.D.
1774	3138	1160	134	125	30	31
1775	3064	1439	156	160	41	39
1776	2554	1020	147	117	37	38
1785	1890	676	144	122	25	25
1791	3690	638	183	142	28	26
1800	1941	200	134	96	22	24
1814	2166	1506	150	142	74	73
1825	1687	1654	168	163	58	56
1836	1987	1294	141	136	48	47

Year.	Mercury. T.	Mercury. Z.D.	Venus. T.	Venus. Z.D.	Mars. T.	Mars. Z.D.	Jupiter. T.	Jupiter. Z.D.	Saturn. T.	Saturn. Z.D.	Uranus. T.	Uranus. Z.D.
1774	19	20	41	42	22	20	20	18	24	23	...	...
1775	39	35	53	48	45	42	36	34	23	20	...	...
1776	32	29	46	42	18	17	40	43	15	14	...	...
1785	15	11	27	26	19	19	22	22	7	5	13	11
1791	34	26	57	54	16	13	41	38	17	16	2	2
1800	3	1	13	12	8	7	16	18	3	2	6	6
1814	...	...	7	7	5	5	30	30	9	10	...	...
1825	...	...	...	...	...	...	3	3	8	8	...	...
1836	...	...	...	...	...	...	7	4	8	3	...	...

TABLE B.

Numbers of Folio Pages of the Journals.

Year.	Folios of Transits.	Folios of Z.D's.	Year.	Folios of Transits.	Folios of Z.D's.	Year.	Folios of Transits.	Folios of Z.D's.
1774	58	24	1794	53	8½	1820	25	25
1775	57	28	1795	75	13	1821	28	27
1776	50	20	1796	53	8	1822	31	29
1777	41	14	1797	55	7	1823	24	22
1778	57	16	1798	53	7	1824	25	23
1779	99	24½	1799	39	4	1825	29	28
1780	68	16½	1800	33	3½	1826	25½	24
1781	62	15	1801	28	7	1827	36	26
1782	29	13½	1802	30	5	1828	30	29
1783	48	18½	1803	15	2	1829	25	21
1784	25	13½	1804–10	No records		1830	33	29
1785	30	14½	1811	45	13	1831	30	21
1786	36	16	1812	42	26½	1832	31	25
1787	40	16	1813	47	20½	1833	38	25
1788	48	23	1814	38	27½	1834	33	27
1789	43	19	1815	39	35	1835	32½	22
1790	55	18	1816	33	33	1836	32	21
1791	76½	21	1817	43	43	1837	31	19
1792	58	10	1818	30	30	1838	8	3
1793	56	10½	1819	39	39			

From these tables it may be estimated that in the period 1774 to 1803 there are about 78,000 transits and 20,000 zenith distances observed, while in the period from 1811 to 1838 there are about 53,000 transits and 41,000 zenith distances. These numbers include the observations of the Sun, Moon, and major planets. It will thus be seen that these bodies have received a

large share of attention, and the reduction and publication of these observations alone would be of enormous value for improving the tables of their movements. I estimate that in the whole period there are more than 8,000 observations of the Sun, a number but little less than that on which Le Verrier's tables were founded, and covering the period when the corrections to the mean longitude of the Sun as deduced from the observations of Greenwich, Paris, and Koenigsberg are most discordant. Thus, we have here an enormous mass of observations of the Sun, Moon, and planets completely independent of Greenwich with regard to personal and instrumental errors, the importance of which for correcting the tables can scarcely be called in question.

Dr. Hornsby's working list seems to include all Flamsteed's stars, and most, if not all, of Bradley's. A list which has come down to us includes 4870 stars, some as faint as the ninth magnitude; but at present I am unable to say how many of these have been actually observed. During the year 1774, and in some of the later years which I have examined, it would seem that attention was chiefly concentrated on a comparatively short list of moderately bright stars, the fainter stars not being so frequently observed. In the year 1774 there have been 2948 observations of the R.A. of 446 stars, and 881 observations of the declination of 136 stars.

Of the star observations the most valuable portion will probably prove to be those previous to 1820. In all questions of proper motions the importance of these observations, filling up, as they do, the long gap between Bradley and Piazzi, or Bradley and Pond, is at once obvious; nor can we say that we have availed ourselves of all possible material for the determination of the constant of precession, and of the Sun's motion in space, until these observations have been fully reduced and discussed.

It may be asked, If Hornsby held a very high opinion of his own observations, why did he not himself give them to the world, instead of devoting so many years of his life to editing Bradley's journals? But it is probable that Hornsby meant his work to be a continuation and extension of that done by Bradley; and when Bradley's observations were, in 1776, presented to the University of Oxford by Lord North, and by the University entrusted to him as editor, he naturally looked upon the publication of Bradley's observations as the first step in a great piece of work, in which the second step would be the publication of his own.

The specimens contained in this paper will, however, enable astronomers to form some estimate for themselves of the value of Dr. Hornsby's observations. The present resources of the Radcliffe Observatory are unfortunately not large enough to encourage us to hope that we could reduce and publish the whole mass of observations without neglecting for a number of years equally, or perhaps even more, important branches of investigation. I have, however, felt it to be my duty to examine into

the quality of these observations and to draw up this brief account of what Dr. Hornsby's journals contain, so as to inform astronomers of the wealth of observations which are here available, and I bring it before the Royal Astronomical Society in the hope that its publication may eventually lead to the reduction and publication of the whole.

Mean R.A. and Decl. of a few of the Stars observed at the Radcliffe Observatory, Oxford, in the year 1774.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	Polaris.	
	$0^h\ 47^m$ s	$+88^\circ\ 5'$ ″
Jan. 23	...	52·02
26	...	52·02
28	...	51·31
29	...	50·85
31	...	52·80
Feb. 2	...	52·47
5	...	53·66
8	...	53·51
20	...	53·70
Mar. 27	9·33	...
29	...	58·89
31	...	56·86
Apr. 1	...	56·00
25	...	57·38
30	8·86	56·36
May 8	...	58·29
9	...	53·11
13	8·34	54·92
15	...	55·48
June 6	9·10	53·23
July 22	10·37	...
27	...	50·40
Oct. 15	7·35	...
20	8·66	...
24	8·42	...

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	Polaris—cont.	
	$0^h\ 47^m$ s	$+88^\circ\ 5'$ ″
Nov. 13	7·29	...
20	8·72	55·93
28	10·79	54·63
29	8·52	54·69
Dec. 1	9·65	55·50
5	...	55·92
6	8·43	55·78
7	...	56·55
9	...	52·70
30	9·84	54·32
	8·91	54·46
	Polaris S.P.	
	$0^h\ 47^m$ s	$+88^\circ\ 5'$ ″
Apr. 20	...	55·35
26	...	52·90
May 1	8·89	51·97
8	...	52·75
9	...	52·89
10	...	53·20
13	8·46	53·59
14	8·24	...
23	...	56·03
27	...	55·54

Polaris: April 30 and July 22. Fluttered.

The weight is determined from a consideration of the number of standard stars used in computing the clock-error and the number of wires at which the transit was observed. It applies, therefore, only to the R.A.

Polaris S.P.—cont.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$0^h 47^m$ s	+88° 5′ ″
June	2	...	56·33
	7	9·09	55·12
	18	...	55·55
July	22	10·36	...
	24	...	55·08
Aug.	7	...	55·23
	9	...	53·45
Oct.	3	...	54·10
	4	...	53·71
	11	...	54·16
	15	7·35	...
	19	8·64	53·54
	23	8·40	53·46
	24	8·48	54·86
Nov.	12	7·32	55·14
	18	...	52·58
	19	7·73	56·81
	20	9·69	...
	22	...	52·92
	28	10·81	57·47
	29	8·54	55·29
	30	9·64	55·64
Dec.	6	8·45	54·02
	24	...	55·17
	30	9·88	56·33
		8·82	54·52

a Arietis.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$1^h 54^m$ s	+22° 23′ ″
Jan.	23	28·66	...
	30	28·86	...
	31	...	6·18
Feb.	2	...	10·05
	5	28·87*	9·65

a Arietis—cont.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$1^h 54^m$ s	+22° 23′ ″
Feb.	8	28·64	11·22
	18	...	8·95
Mar.	13	28·71	...
	14	28·69	...
	15	28·68	...
	28	28·85	...
	31	28·67	...
May	15	28·47	...
June	12	28·64	...
	17	28·47	...
July	22	28·50	2·72
Nov.	13	28·54	...
		28·65	8·13

δ Arietis.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$2^h 58^m$ s	+18° 51′ ″
Jan.	26	44·38	...
	28	44·50*	...
Feb.	5	44·78	32·72
	8	44·60*	29·33
		44·57	31·03

η Tauri.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$3^h 34^m$ s	+23° 23′ ″
Jan.	27	5·49*	...
	28	5·47†	...
	29	5·40*	25·53
	30	5·52	...
	31	5·32	...
Feb.	5	5·15	29·58
	6	5·25	29·11
	8	5·27*	...
	16	5·34	29·00
	20	...	26·36

a Arietis : February 2. Windy, and plumb-line unsteady.

* Half weight given to these observations.
† Quarter weight given to these observations.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	η Tauri—cont.	
	$3^h\ 34^m$	$+23°\ 23'$
	s	″
Feb. 21	5·42	...
24	...	26·92
Mar. 13	5·38	25·83
29	5·12	...
31	5·11*	...
July 22	5·19*	...
23	5·32	...
Dec. 6	5·35	...
	5·32	27·48
	Aldebaran.	
	$4^h\ 22^m$	$+16°\ 2'$
	s	″
Jan. 23	58·49*	11·21
24	...	12·95
26	58·46	...
29	...	12·46
31	...	11·39
Feb. 28	58·40*	...
Mar. 13	58·69	12·68
16	58·52	11·43
27	58·40	13·17
29	58·45	...
30	58·53	11·65
31	58·52	11·41
Apr. 1	58·54	11·79
10	58·57	10·74
21	...	13·12
May 1	58·36	7·38
15	58·60	...
June 17	58·58	...
July 22	58·53	15·43
23	58·40	10·48
24	58·53	9·00
25	58·35	8·87
26	58·45	...

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	Aldebaran—cont.	
	$4^h\ 22^m$	$+16°\ 2'$
	s	″
July 29	58·57	...
30	58·52	7·94
31	58·57	...
Aug. 1	58·68*	15·75
2	58·41	14·04
6	58·39	11·94
9	58·53	...
10	58·53	...
11	58·45	11·29
17	58·49	13·32
19	58·39	11·56
20	58·48	...
22	58·40	...
	58·49	11·71
	Capella.	
	$5^h\ 0^m$	$+45°\ 44'$
	s	″
Jan. 26	1·84*	...
Feb. 5	1·62*	...
24	...	34·81
26	1·87	...
Mar. 13	1·63*	...
14	1·53	.
16	1·59	37·38
27	1·62	...
28	1·54	...
29	1·74	...
31	1·78	...
Apr. 1	1·66	...
10	1·65	...
13	1·74	37·53
May 1	1·63	...
15	1·58	...
June 12	1·62	...
17	1·59	...

Aldebaran: July 25 and 30. Air undulated much.

* Half weight given to these observations.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	Capella—cont.	
	$5^h\,0^m$	$+45°\,44'$
	s	″
July 22	1·80	...
23	1·70	37·25
25	1·62	...
26	1·63	...
27	1·75	...
29	1·67	38·38
30	1·60	35·62
31	1·55	41·18
Aug. 1	1·51	38·00
2	1·53	37·79
6	1·68	...
10	1·88	...
11	1·76	...
12	1·84	...
16	1·72	...
17	1·79	...
19	1·74	...
20	1·69	...
22	1·60	...
28	1·49	...
Sept. 4	1·53*	...
7	1·80	...
8	1·90	...
	1·73	37·55
	Capella S.P.	
	$5^h\,0^m$	$+45°\,44'$
	s	″
July 23	1·01†	35·55
Aug. 10	...	39·69
21	1·44	33·62
	1·35	36·29
	β Tauri.	
	$5^h\,12^m$	$+28°\,23'$
	s	″
Feb. 5	1·21*	...
Mar. 13	1·18	...
16	1·23	...

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	β Tauri—cont.	
	$5^h\,12^m$	$+28°\,23'$
	s	″
Mar. 27	1·29	...
30	1·19	...
31	1·34	...
Apl. 1	1·36	...
10	1·23	...
13	1·38*	...
27	...	41·99
May 1	1·16	...
16	1·28	...
June 12	1·34	...
17	1·15	...
July 22	1·36	...
23	1·30	...
24	1·37*	...
26	1·34	...
30	1·22	...
31	1·07	...
Aug. 1	1·17	...
2	1·27	...
6	1·30	45·37
10	1·26	...
11	1·35	46·87
12	1·37	45·04
16	1·35	...
17	1·39	...
19	1·20	...
22	1·17	45·07
24	...	43·25
26	1·20	...
28	1·20	43·46
Sept. 4	1·33	...
7	1·13	...
8	1·19	...
	1·26	44·44

Capella: July 25. Air undulated much. September 8. Air unsteady.
β Tauri: September 8. Air unsteady.

* Half weight given to these obs. † Quarter weight given to these obs.

μ Geminorum.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	$6^h\ 9^m$	$+22°\ 36'$
	s	″
Feb. 20	17·12	37·72
21	17·22	39·44
Mar. 31	...	31·83
Apr. 1	17·30	33·50
Sept. 19	17·14	37·07
Oct. 2	17·35	38·65
3	...	33·52
4	17·28	33·67
7	17·21	35·45
	17·23	35·65

Sirius.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	$6^h\ 35^m$	$-16°\ 25'$
	s	″
Feb. 26	11·25	...
28	11·00	...
Mar. 1	11·08	...
13	11·11	...
14	11·28*	...
16	11·12	...
24	11·21	...
27	11·22	...
28	11·19	17·88
30	11·22	17·80
31	11·16	17·54
Apr. 1	11·17	16·77
13	11·14	15·80
May 1	11·18	18·40
15	11·21	18·26
June 18	11·36	...
July 23	11·25	...
24	11·14	19·73
25	11·31*	...
31	11·19*	...
Aug. 1	11·21	15·91
2	11·24	20·10

Sirius—cont.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	$6^h\ 35^m$	$-16°\ 25'$
	s	″
Aug. 6	11·15	15·85
11	11·10	14·06
12	10·98	16·37
16	11·22	16·81
17	11·16	17·55
19	11·14	19·68
20	11·21	...
22	11·35	19·10
23	11·37	...
26	11·31	...
28	11·31	18·38
Sept. 4	11·41	18·04
7	11·30	18·11
8	11·04	12·83
9	11·19	17·07
11	11·18	16·78
15	11·29	16·20
18	11·22	15·19
19	11·22	14·44
28	...	11·83
Oct. 1	...	15·69
2	11·09	13·45
3	11·03	16·62
4	11·19	17·06
7	11·35	...
	11·20	16·43

Castor.

Day.	Mean R.A. 1774·0.	Mean Decl. 1774·0.
	$7^h\ 20^m$	$+32°\ 21'$
	s	″
Feb. 17	8·78*	...
25	8·67*	...
28	8·55*	...
Mar. 11	8·67	...
13	8·85*	...
16	8·85	...

Sirius: July 24. Fluttered much. August 1. Air undulated.

* Half weight given to these observations.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
Castor—cont.			
		$7^h\ 20^m$	$+32°\ 21'$
		s	″
Mar.	25	8·72	...
	26	8·82*	...
	27	8·60	...
	30	8·71	...
Apr.	1	8·46	...
	8	8·57*	...
	10	8·64*	...
	13	8·77*	...
May	1	8·73	44·58
	15	8·65	...
June	7	8·65	...
	13	8·74	...
July	22	8·68*	...
	23	8·80	...
	31	8·37*	...
Aug.	1	8·56	...
	6	8·46	45·76
	11	8·73	...
	17	8·64	...
	19	8·79	45·41
	20	8·71	...
	22	8·74	...
Sept.	4	8·63	48·62
	7	8·78	...
	8	8·86	...
	9	8·84	...
	10	8·72	...
	11	8·69	46·91
	15	8·69	46·84
	18	8·59	45·98
	28	8·71	48·06
Oct.	1	8·80	48·48
	2	8·88	...

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
Castor—cont.			
		$7^h\ 20^m$	$+32°\ 21'$
		s	″
Oct.	3	8·92	46·23
	4	8·79	47·93
	7	8·73	...
	9	8·90†	...
	10	9·02	...
		8·74	46·80
Radcliffe (1845), 2218.			
		$8^h\ 24^m$	$+85°\ 1'$
		s	″
Oct.	24	19·65*	56·42
	25	17·34*	55·73
	26	19·14*	55·89
		18·71	56·01
Radcliffe (1845), 2218 *S. P.*			
		$8^h\ 24^m$	$+85°\ 1'$
		s	″
Oct.	25	17·41	56·55
	26	...	57·58
			57·07
Regulus.			
		$9^h\ 56^m$	$+13°\ 3'$
		s	″
Mar.	13	18·88	...
	24	18·77	...
Apr.	13	18·86	...
	26	...	48·17
May	1	18·97*	46·58
	8	18·86	50·37
	10	18·95	46·55
	15	18·94	49·17
June	1	...	50·69
	4	...	51·71
July	20	18·89	...
	24	18·84	...

Castor: August 1. Air undulated much. August 6. Saw the small star; it preceded about 0s·2.

* Half weight given to these observations.
† Quarter weight given to these observations.

Regulus—cont.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$9^h 56^m$	$+13° 3'$
		s	"
July	25	18·87	...
	28	18·91	...
Aug.	2	18·81	...
	7	18·71	...
	10	18·78	...
Sept.	4	18·87	...
	7	18·87	...
	8	19·00	...
	18	18·89	...
Oct.	2	18·88	44·90
	3	18·96	48·08
	10	...	47·78
	15	18·90	...
	24	18·84	50·34
	25	18·83	46·80
	26	18·83	...
Nov.	9	18·81	...
	22	...	47·92
		18·87	48·39

γ Leonis.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$10^h 7^m$	$+20° 58'$
		s	"
Mar.	24	28·84	...
Apr.	8	28·88†	...
	18	28·68*	...
	26	28·74*	...
May	1	28·93	37·28
	7	28·85	...
	8	29·04	38·06
Aug.	7	28·60	...
Sept.	10	29·04	...
	14	28·86*	...
	18	28·79*	...
	19	28·85	...
Oct.	2	29·11	...
	3	29·06	...
	10	29·03	...
	11	28·96*	...
	15	28·65	...
	24	28·98	...
	25	28·84	36·65
	26	28·86	35·48
	28	29·06*	...
Nov.	9	28·77	37·58
	22	28·75*	...
		28·89	37·01

γ Leonis—cont.

β Virginis.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$11^h 38^m$	$+3° 2'$
		s	"
Jan.	23	55·35*	18·68
Mar.	13	55·53*	...
	26	55·29	...
	27	55·56	...
May	1	55·46*	16·11
	9	55·34	...
	10	55·30	14·58
	13	55·20*	16·33
	23	55·31	18·70
June	1	55·40	...
	18	55·24	...
Nov.	12	55·21	...
	18	55·34	...
	19	55·53*	...
		55·35	16·88

12 Canum Ven.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$12^h 45^m$	$+39° 32'$
		s	"
June	7	25·19	...
	18	25·33	...
July	15	25·36	...
	16	25·34	...

* Half weight given to these observations.
† Quarter weight given to these observations.

12 *Canum Ven.*—cont.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$12^h 45^m$	+39° 32′
		s	″
Aug.	2	25·42	...
	7	25·37*	34·08
	9	25·48*	...
Oct.	19	25·45*	...
	27	25·32	...
Nov.	9	25·38	...
	12	25·39	...
	17	25·42	...
	18	25·44	...
	19	25·26	31·68
	20	25·33	...
	29	25·08	...
	30	25·10*	35·69
Dec.	6	25·33*	...
		25·33	33·82

Spica.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$13^h 13^m$	−9° 58′
		s	″
May	9	18·74	...
June	18	...	28·09
	26	...	29·27
July	15	...	32·26
	16	...	33·50
	20	18·73	...
	24	18·75	34·43
Aug.	5	18·78	32·53
	7	18·90	31·13
	9	...	30·77
	10	18·82	30·52
	17	18·56	...
	19	...	32·52
	20	...	31·96
	21	18·82	...
	23	18·76	33·58
	27	18·92	...

***Spica*—cont.**

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$13^h 13^m$	−9° 58′
		s	″
Oct.	5	18·78	...
	19	18·65	...
	24	18·74	...
	25	18·94	...
	26	18·91	...
Nov.	12	...	27·92
	18	18·78	29·99
	22	...	28·44
	28	18·79	28·45
	29	18·89	28·58
	30	...	28·48
Dec.	12	...	29·60
	24	18·65	29·02
		18·78	30·51

Arcturus.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$14^h 5^m$	+20° 22′
		s	″
June	26	...	4·95
	28	...	1·78
July	14	...	3·86
	17	...	2·67
	20	21·58	...
	24	21·64	...
	25	21·63	...
Aug.	2	21·38	3·66
	5	21·59	1·94
	7	21·65	3·31
	20	...	2·84
	21	21·51	3·43
	23	21·57	2·46
	24	21·51	2·87
	27	21·54	2·85
	29	21·54	...
Sept.	8	21·66	2·87
	12	21·59	4·10

* Half weight given to these observations.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		***Arcturus*—cont.**	
		$14^h 5^m$	$+20° 22'$
		s	″
Sept.	13	21·49	4·31
Oct.	3	21·61	0·99
	5	21·61	2·23
	7	21·54	3·53
	8	21·61	1·80
	9	21·55	...
	15	21·52	3·61
	16	21·56	2·86
	20	21·64	...
	25	21·75	...
Nov.	9	21·56	...
	12	...	2·20
	16	...	3·54
	18	21·61	3·29
	22	...	3·28
	28	21·59	3·60
	30	...	4·10
Dec.	8	...	3·54
	12	...	3·71
	14	...	3·32
	21	21·56	4·58
	23	21·47	3·36
	24	21·24	3·98
		21·56	3·19
		a Coronæ.	
		$15^h 25^m$	$+27° 29'$
		s	″
ug.	2	7·58	...
	5	7·48	14·54
	7	7·60	16·91
	21	7·54	14·73
	24	7·50	13·94
pt.	13	7·50	...
t.	5	7·50	...
	15	7·54	...

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		***a Coronæ*—cont.**	
		$15^h 25^m$	$+27° 29'$
		s	″
Oct.	24	7·47	...
	25	7·47	...
Dec.	23	7·52	...
	24	7·66	15·90
		7·53	15·20
		Antares.	
		$16^h 15^m$	$-25° 54'$
		s	″
Jan.	24	34·99	...
	25	34·95	...
	29	34·86*	36·76
July	15	...	41·56
	20	35·18	...
Aug.	2	35·19	...
	5	35·05	...
	7	34·93*	40·90
	10	35·05	41·19
	21	35·06	40·18
	24	35·15	43·29
Sept.	8	35·07	39·65
	12	35·06	...
	20	35·10	40·07
	30	35·09	38·83
Oct.	3	34·94	42·44
	5	35·12	39·85
	15	35·07	...
Dec.	23	35·00	...
	24	35·10	...
		35·06	40·43
		a Herculis.	
		$17^h 4^m$	$+14° 39'$
		s	″
Aug.	21	21·10	...
	24	20·97	45·91
Sept.	12	21·01	...

* Half weight given to these observations.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		a Herculis—cont.	
		17h 4m	+14° 39′
		s	″
Oct.	5	21·17	...
	7	21·19	...
	8	20·96	...
	9	21·02	...
	15	21·11	...
Nov.	10	21·19	...
		21·08	
		a Lyræ.	
		18h 29m	+38° 35′
		s	″
Jan.	23	...	2·16
	24	17·45	6·21
	25	17·53	6·04
	29	17·22	6·16
	30	...	5·77
Feb.	4	...	6·74
	15	...	6·81
	19	...	4·69
	26	17·38	6·68
	28	...	6·95
Mar.	12	17·19	5·07
	13	17·30	6·78
	14	17·28	4·10
Aug.	21	17·14	...
Sept.	12	17·29	...
	20	17·39	...
	27	...	6·28
	30	17·31	6·94
Oct.	1	17·18	6·03
	3	17·35	2·11
	5	17·33	4·13
	6	17·35	5·64
	7	17·25	...
	8	17·30	...

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		a Lyræ—cont.	
		18h 29m	+38° 35′
		s	″
Oct.	9	17·40	...
	12	17·39	...
	14	17·39	...
	15	17·46	...
	16	17·30	5·29
	20	17·41	5·06
	21	...	4·29
	25	17·39	3·69
	26	17·39	...
Nov.	13	17·43	...
	19	17·41	5·45
Dec.	22	17·48	7·73
	24	17·37	4·74
		17·35	5·44
		ζ Lyræ.	
		18h 36m	+37° 22′
		s	″
Sept.	4	59·49†	...
Oct.	7	59·68	50·98
	8	59·73	50·07
	9	59·69	50·45
	12	59·63	50·40
	14	59·58	...
	15	59·67	...
		59·66	50·47
		δ Ursæ Min.	
		18h 44m	+86° 32′
		s	″
Mar.	28	45·47	...
Sept.	27	...	9·09
	30	...	5·87
Oct.	1	45·07	9·89
	5	45·52	7·62

* Half weight given to these observations.
† Quarter weight given to these observations.

δ Ursæ Min.—cont.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$18^h\ 44^m$	$+86°\ 32'$
		s	″
Oct.	7	46·08	7·50
	8	44·90	10·39
	20	44·88	...
	21	...	8·32
		45·32	8·38

δ Ursæ Min. S. P.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$18^h\ 44^m$	$+86°\ 32'$
		s	″
Feb.	16	...	9·58
Mar.	27	45·80	...
	28	45·47	...
Oct.	1	45·08	...
	3	...	6·80
	4	45·51	7·14
	7	45·47	8·76
		45·47	8·07

θ Lyræ.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$19^h\ 8^m$	$+37°\ 44'$
		s	″
Sept.	12	31·53	...
	20	31·44	...
	27	31·67	...
	30	31·65	33·90
Oct.	1	31·65	33·46
	3	31·49*	34·11
	5	31·40	33·95
	6	31·49*	34·83
	7	31·62	33·88
	15	31·58	...
		31·56	34·02

χ Aquilæ.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$19^h\ 31^m$	$+11°\ 18'$
		s	″
Oct.	1	56·11	...
	3	55·92	32·94
	6	55·92	...
	8	...	32·84
	9	...	31·61
	14	56·00	...
		55·99	32·46

α Aquilæ.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$19^h\ 39^m$	$+8°\ 17'$
		s	″
Jan.	24	45·23	15·00
	25	45·19*	12·90
	29	45·31	11·75
	30	...	12·95
Feb.	6	...	14·06
	7	45·21	12·53
	16	...	13·97
	22	...	12·02
	26	45·15*	14·25
	28	...	15·01
Mar.	12	45·28	14·38
	13	45·27	12·82
	14	45·31	...
	28	45·20	11·26
Sept.	8	45·15	...
	13	45·28	...
	20	45·18	...
	27	...	11·05
	30	45·23	...
Oct.	1	45·26	...
	3	45·22	...
	5	45·28	...
	6	45·23	...
	8	...	14·33
	9	...	12·04
	12	45·02	...
	14	45·24	...
	16	45·28	...
	26	45·20	...

* Half weight given to these observations.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		α Aquilæ—cont.	
		19h 39m s	+8° 17′ ″
Oct.	29	45·25	...
Nov.	13	45·30	...
	16	...	11·42
	26	...	12·24
	27	45·37	...
	30	45·26	11·53
Dec.	9	...	12·90
	11	45·27	11·56
	25	45·29	12·60
		45·24	12·84
		α Cygni.	
		20h 33m s	+44° 28′ ″
Jan.	23	44·08*	52·75
Feb.	4	43·87	57·26
	26	44·14*	...
Mar.	12	43·87*	...
	13	43·91*	...
	14	43·84	55·42
	28	43·87	...
Apr.	9	...	56·89
	12	...	55·35
Oct.	5	43·85	...
	9	43·88	...
	12	43·95	...
	14	44·03	...
	15	43·85	...
	16	43·99	...
	25	43·93	...
	26	44·09	...
Nov.	24	43·97	...
	27	44·04	54·76
	29	43·93	53·21
	30	43·90	55·44

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		α Cygni—cont.	
		20h 33m s	+44° 28′ ″
Dec.	6	44·02	55·86
	9	...	56·21
	11	43·97	55·44
	22	44·04	...
	25	44·20	...
		43·96	55·33
		ε Pegasi.	
		21h 33m s	+8° 50′ ″
May	3	5·10*	...
Oct.	24	5·38	...
	27	5·36*	...
Nov.	21	5·22	...
	24	5·24	...
	26	5·37	...
	30	5·21	54·96
Dec.	15	5·34	53·69
	25	5·33	52·21
		5·29	53·62
		21 Piscis Aust.	
		22h 38m s	−30° 43′ ″
Oct.	12	50·44	39·40
	14	50·63	38·19
	15	50·31	...
	20	50·41	...
	24	50·48	40·70
Nov.	28	50·50	36·47
	29	50·47	37·26
Dec.	6	50·77*	38·30
	11	...	38·84
		50·48	38·45

* Half weight given to these observations.

Fomalhaut.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$22^h\ 45^m$	$-30°\ 48'$
		s	″
Sept.	30	6·95	...
Oct.	5	7·04	...
	7	7·14	...
	12	7·07	49·80
	14	6·93	46·65
	15	7·00	...
	20	7·12	...
	24	7·22	47·32
	25	6·95	...
	26	7·09	...
Nov.	24	7·23	50·24
	27	7·01	46·97
	29	6·91	...
	30	7·07	...
Dec.	6	7·26	47·45
	11	7·00	52·67
	22	7·00	47·23
	25	7·01	47·50
	30	...	51·56
		7·06	48·74

Piazzi xxii., 262.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$22^h\ 47^m$	$-30°\ 40'$
		s	″
Oct.	12	11·48	...
	15	11·46	...
	24	11·41	...
	25	11·44	...
	26	11·57	...
Nov.	20	11·48	...
	24	11·62	...
	27	11·38	...
	28	11·43	3·48
	29	11·40	5·06
	30	11·30	5·88
Dec.	6	11·32	...
		11·44	4·81

α Androm.

Day.		Mean R.A. 1774·0.	Mean Decl. 1774·0.
		$23^h\ 56^m$	$+27°\ 50'$
		s	″
Mar.	14	44·71	...
	24	44·82	...
	28	44·60	...
Apr.	30	...	32·68
Nov.	29	44·72	...
Dec.	5	...	32·83
	6	44·65	...
	15	...	31·10
		44·70	32·20

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. FEBRUARY 9, 1900. No. 5

Professor G. H. DARWIN, M.A., LL.D., F.R.S., PRESIDENT, in the Chair;

William Henry Robinson, Offendene, Walsall, Staffordshire, was balloted for and duly elected a Fellow of the Society.

The following Candidate was proposed for election as a Fellow of the Society :—

Thomas C. Bush, Somerville, Wells Road, Bath (proposed from personal knowledge by the Rev. D. Higham Sparling).

REPORT OF THE COUNCIL TO THE EIGHTIETH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1898 December 31	247	388	635	44	1	680
Since elected	+ 6	+ 21	...	+ 4	...	...
Deceased	− 3	− 11	...	...	...	...
Resigned	...	− 7	...	...	...	...
Removals	+ 3	− 3	...	...	...	...
Expelled	...	− 6	...	...	...	...
1899 December 31	253	382	635	48	1	684

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1899 January 1:—						
At Bankers', as per Pass-book	542	16	3			
Cheques not credited till 1899	6	6	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	2	18	2			
In hand of Assistant Secretary on Petty Cash Account	13	6	1			
				565	6	6
Three quarters' Dividends on £13,200 Consols, 2¾ per cent.	263	3	9			
Dividends on £1,250 Metropolitan 3-per-cent. Stock	36	5	0			
,, £932 19 0 Metropolitan 2½-per-cent. Stock	22	11	0			
One quarter Dividend on £3,400 East Indian Railway 3-per-cent. Debenture Stock	24	13	0			
Half-year Dividend on £1,100 Commercial Gas Company 4½-per-cent. Debenture Stock ...	23	18	6			
Interest received from Brokers for Stock not delivered	18	11	7			
				389	2	10
Received on account of Subscriptions:—						
Arrears	155	8	0			
Annual Contributions for 1899	594	6	0			
,, ,, 1900	6	6	0			
Admission Fees	56	14	0			
First Contributions	38	17	0			
				851	11	0
Composition Fees				168	0	0
Sales of Publications:—						
At Williams and Norgate's, 1898	16	3	6			
At Society's Rooms, 1899	61	13	0			
Sales of Photographs, 1899	23	9	6			
				101	6	0
Received from Mrs. Knott in aid of Expenses of Printing *Memoirs*, vol. lii.				250	0	0
Income Tax refunded by Commissioners of Inland Revenue				14	2	0
				£2,339	8	4

Audited and found correct, January 19, 1900,

RICHARD INWARDS,
W. B. GIBBS.

Astronomical Society, from 1899 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications ...	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing, &c., *Monthly Notices*	353	17	3			
" *Memoirs*, vol. lii.	366	15	6			
" " vol. liii.	338	5	0			
" List of Fellows and Miscellaneous ...	24	5	0			
Engraving Blocks for *Monthly Notices*	4	17	6			
				1,088	0	3
Computation of Ephemerides				15	0	0
Reproduction of Photographs				15	8	4
Turnor and Horrox Fund: Purchases for Library	7	18	2			
Council Grant: ditto	16	1	3			
				23	19	5
Clerk's Wages	40	4	0			
Postage and Telegrams	80	18	7			
Carriage of Parcels	2	12	9			
Stationery (Spottiswoode & Co.)	3	11	4			
Stationery and Office Expenses	5	11	4			
Envelopes for storing Photographs	3	13	0			
Address to Sir G. Stokes	3	18	6			
				140	9	6
Expenses of Meetings	20	0	0			
Lantern Expenses	6	6	8			
Time Signal: Rental of Wire (1898 and 1899) ...	10	0	0			
				36	6	8
House Expenses	68	8	10			
Coals and Gas	44	3	10			
Electric Lighting	5	19	10			
Furniture, &c.	17	8	0			
Sundry Fittings and Repairs	7	12	8			
Sundries	4	8	8			
				148	1	10
Dallmeyer & Co., for two Abney Lenses				22	13	9
Lee and Janson Fund Grant				5	0	0
Invested (see separate Account)	64	9	3			
Interest from Brokers invested (see separate Account)	18	11	7			
				83	0	10
Cheque-book and Deductions on Cheques				0	10	1
Balances, 1899 December 31:—						
At Bankers', as per Pass-book	400	10	2			
Cheques not credited till 1900	6	6	0			
In hand of Assistant Secretary on account of Council Grant for Purchase of Books	8	18	9			
In hand of Assistant Secretary on Petty Cash Account	18	11	3			
				434	6	2
Cheques outstanding 1898 December 31				14	9	6
				£2,339	8	4

Treasurer's Account of the Sale
ordered by the Council

		£ s. d.	£ s. d.
Aug. 10.	To Sale of £13,200 Consolidated 2¾-per-cent. Annuities @ 105⅝ ...	13,909 10 0	
	Power of Attorney and Stamp ...	0 15 0	
			13,908 15 0
Aug. 15.	To Cash	59 16 0	
Oct. 13.	To Interest, 3 per cent. on £1,730 4 6 (Gas Light and Coke Company Stock deferred), Aug. 16 to Oct. 13	8 4 10	
Oct. 27.	To Interest, 3 per cent. on £1,747 5 3 (Stock purchased but not delivered), Aug. 16 to Oct. 27 ...	10 6 9	
Oct. 31.	To Cash	4 13 3	
			83 0 10
			£13,991 15 10

of Consols and Reinvestment,
1899 *June* 9.

	£	s.	d.	£	s.	d.
1899. By purchase of—						
£3,200 London and North-Western Railway 3-per-cent. Debenture Stock @ 111¼	3,560	0	0			
Stamp, Brokerage, &c.	27	1	6			
				3,587	1	6
£3,600 Midland Railway 2½-per-cent. Debenture Stock @ 94	3,384	0	0			
Stamp, Brokerage, &c.	25	12	9			
				3,409	12	9
£3,400 East Indian Railway 3-per-cent. Debenture Stock @ 102	3,468	0	0			
Stamp, Brokerage, &c.	26	7	0			
				3,494	7	0
£1,700 Gas Light and Coke Company 3-per-cent. Debenture Stock @ 101...	1,717	0	0			
Stamp, Brokerage, &c.	13	4	6			
				1,730	4	6
£160 Gas Light and Coke Company 3-per-cent. Debenture Stock @ 101...	161	12	0			
Stamp, Brokerage, &c.	1	14	10			
				163	6	10
£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock @ 145 ...	1,595	0	0			
Stamp, Brokerage, &c.	12	3	3			
				1,607	3	3
				£13,991	15	10

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1899, and have found and certified the same to be correct. The cash in hand on December 31, 1899, including the balance at the bankers', &c., amounted to £434 6*s.* 2*d.*

During the past year considerable changes have been made in the investments of the Society, particulars of which are set forth in the account accompanying this report.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
W. B. GIBBS.

Trust Funds.

The Turnor Fund: A sum of £464 18*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6*s.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1900 *January* 1.

	£	s.	d.	£	s.	d.
Balances, 1899 December 31:—						
At Bankers', as per Pass-book	400	10	2			
Cheques not credited till 1900	6	6	0			
In hand of Assistant Secretary on account of Council Grant for purchase of books ...	8	18	9			
In hand of Assistant Secretary on Petty Cash Account	18	11	3			
				434	6	2
Due on account of Subscriptions:—						
3 Contributions of 5 years' standing	31	10	0			
6 " 4 "	50	8	0			
7 " 3 "	44	2	0			
31 " 2 "	130	4	0			
60 " 1 "	126	0	0			
2 Admission Fees and First Contributions ...	6	6	0			
	388	10	0			
Less 3 Contributions paid in advance ...	6	6	0			
				382	4	0
Due from Messrs. Williams and Norgate for sales of Publications during 1899				32	19	10

£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (née Gwilt) Fund.

£3,200 London and North Western Railway 3-per-cent. Debenture Stock.

£3,600 Midland Railway 2½-per-cent. Debenture Stock.

£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Two Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXXI.	134	...
I. Part 2	41	...	XXXII.	145	...
II. Part 1	50	3	XXXIII.	154	...
II. Part 2	16	3	XXXIV.	157	...
III. Part 1	65	1	XXXV.	104	2
III. Part 2	82	1	XXXVI.	187	8
IV. Part 1	78	3	XXXVII. Part 1	330	7
IV. Part 2	89	3	XXXVII. Part 2	278	8
V.	100	3	XXXVIII.	263	1
VI.	117	6	XXXIX. Part 1	228	3
VII.	140	3	XXXIX. Part 2	233	3
VIII.	124	3	XL.	248	...
IX.	130	3	XLI.	395	1
X.	142	...	XLII.	224	3
XI.	148	...	XLIII.	223	...
XII.	153	...	XLIV.	206	1
XIII.	153	...	XLV.	238	...
XIV.	360	...	XLVI.	214	2
XV.	134	...	XLVII. Part 1	3	...
XVI.	157	1	XLVII. Part 2	18	...
XVII.	140	1	XLVII. Part 3	2	...
XVIII.	133	1	XLVII. Part 4	10	...
XIX.	143	...	XLVII. Part 5	8	...
XX.	133	1	XLVII. Part 6	9	...
XXI. Part 1	244	...	XLVII.	197	1
XXI. Part 2	98	...	XLVIII. Pt. 1	227	2
XXI. 1 & 2 (together)	54	...	XLVIII. Pt. 2	231	1
XXII.	157	...	XLIX. Part 1	363	...
XXIII.	142	...	XLIX. Part 2	241	...
XXIV.	147	1	L.	235	1
XXV.	153	...	LI.	271	1
XXVI.	163	1	LII.	365	1
XXVII.	417	1	LIII.	394	4
XXVIII.	372	...	Index to *Memoirs*	619	1
XXIX.	395	1			
XXX.	147	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXII.	106	5
II.	58	...	XXXIII.	90	...
III.	...	...	XXXIV.	65	1
IV.	...	...	XXXV.	51	...
V.	...	...	XXXVI.	26	1
VI.	42	...	XXXVII.	31	3
VII.	2	...	XXXVIII.	95	2
VIII.	152	2	XXXIX.	95	...
IX.	24	3	XL.	104	3
X.	171	1	XLI.	103	5
XI.	183	...	XLII.	112	1
XII.	105	2	XLIII.	108	2
XIII.	176	2	XLIV.	111	2
XIV.	175	3	XLV.	115	1
XV.	167	2	XLVI.	108	...
XVI.	154	1	XLVII.	124	2
XVII.	165	1	XLVIII.	118	...
XVIII.	242	...	XLIX.	109	7
XIX.	51	...	L.	109	10
XX.	31	...	LI.	110	8
XXI.	16	...	LII.	108	11
XXII.	30	...	LIII.	112	14
XXIII.	17	...	LIV.	112	14
XXIV.	22	...	LV.	125	...
XXV.	13	...	LVI.	124	3
XXVI.	9	...	LVII.	130	3
XXVII.	3	...	LVIII.	128	7
XXVIII.	70	...	LIX.	132	7
XXIX.	50	...	1st Index ...	543	2
XXX.	61	2	2nd „ ...	800	...
XXXI.	90	...			

Library Catalogue ... ... 547 ...

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LIX., no complete volumes can be formed from the separate numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the *Pleiades*	Isaac Roberts
5	Nebula M 74 *Piscium*	Isaac Roberts
6	Great Nebula in *Orion*	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in *Perseus*	E. E. Barnard
9	Comet *c* 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet *a* 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η *Argûs*	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Lœwy and Puiseux
13	Comet *c* 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet *c* 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet *c* 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet *a* 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet *f* 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet *a* 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Lœwy and Puiseux
20	Nebula in *Andromeda*	Isaac Roberts
21	*Jupiter*, 1892 September 26	Lick Observatory
22	Cluster M 13 *Herculis*	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age $7^d\ 3^h$)	Lick Observatory
26	The Moon (Age $12^d\ 6\frac{1}{2}^h$)	Lick Observatory
27	The Moon (Age $16^d\ 18^h$)	Lick Observatory
28	The Moon (Age $23^d\ 8^h$)	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of *Maginus*)	Lœwy and Puiseux
32	The Moon (Age $14^d\ 1^h$)	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 *Lyræ*	
42	Nebulæ M 81, 82 *Ursæ Majoris*	
43	Cluster M 56 *Lyræ* (enlarged)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in *Orion*	W. E. Wilson
57	Dumb-bell Nebula, *Vulpecula*	W. E. Wilson
58	Spiral Nebula, *Canes Venatici*	W. E. Wilson
59	Spiral Nebula, *Canes Venatici* (enlarged)	W. E. Wilson
60	Annular Nebula in *Lyra*	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in *Andromeda*	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills
68	Annular Nebula, *Lyra*	Lick Observatory
69	Dumb-bell Nebula, *Vulpecula*	Lick Observatory
70	Spiral Nebula, *Canes Venatici*	Lick Observatory
71	Spiral Nebula, *Ursa Major*	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
72	Trifid Nebula, *Sagittarius*	Lick Observatory
73	Great Nebula in *Orion*	Lick Observatory
74	Cluster M 13 *Herculis*	Lick Observatory
75	Solar Surface with Faculæ	G. E. Hale
76	Faculæ and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 (¾ sec.)	W. H. M. Christie
78	Nebula H V. 14 *Cygni*	W. E. Wilson

Nos. 44–55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44–55 and Nos. 64 and 65 are also supplied as transparencies, 6¼ inches square.

Price of prints, 1*s.* 6*d.* each; lantern slides, 1*s.* each; packing and postage extra.

Unmounted prints, 1*s.* each, can be obtained to order.

Transparencies, 6¼ inches square (Nos. 44–55 and Nos. 64 and 65), 3*s.* 6*d.* each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.

No. 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.
„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.
„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 33. (7) 2-foot navy telescope.
„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.
„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.
„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.
„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.
„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope,

by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

No. 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane $2\frac{3}{8}$-inch speculum, artificial horizon and stand.

„ 59. (33) $2\frac{1}{2}$-inch circular level horizon, by Dollond.

No. 60. (34) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. $3\frac{1}{4}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevallier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.

No. 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. Two old sun-dials.
„ 118. A 10½-inch sixteenth-century celestial globe, on bronze tripod stand.
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eye-pieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with 2½-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar. [Presented by the executors of the late Sidney Waters.]
„ 133. 3¼-inch equatorial by Ross, with tall tripod stand, equa-

torial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]

No. 134. Old transit instrument, 2-inch aperture and 3-feet focal length, formerly belonging to Dr. Longfield, of Cork. [Presented by the executors of the late R. J. Lecky.]

„ 135. Globe of Mars, by E. M. Antoniadi. [Presented by M. Antoniadi.]

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
1 Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.
„ 30. (4) $3\frac{1}{4}$-inch equatorial and stand, to Mr. C. H. Johns.
„ „ Double-image micrometer, to the Rev. W. J. B. Roome.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 57. (31) Box sextant, to Dr. A. A. Common.
„ 69. (43) Telescope with rock-crystal object glass, to Sir W. Huggins.
„ 72. (*c*) Polarimeter, to Professor C. Michie Smith.
„ 74. Registering spectroscope, to Mr. Shackleton.
„ 78. $9\frac{1}{4}$-inch reflector and stand, to the Rev. W. J. B. Roome.
„ 98. 2-ft. 6-in. navy telescope, to the Rev. J. M. Bacon.
„ 120. 6-prism spectroscope by Browning, to Mr. E. B. Knobel.
„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. E. Wilson.
„ 125. 6-inch refractor, by Simms, to Dr. A. A. Common.
„ 128. Bichromate battery, to the Rev. W. J. B. Roome.
„ 132. The *Waters* equatorial, to Mr. E. W. Maunder.
„ 133. $3\frac{1}{4}$-in. equatorial, by Ross, to Mr. A. W. Roberts.

The Gold Medal.

The Council have awarded the Society's Gold Medal to M. Henri Poincaré, for his researches in celestial mechanics. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vols. LII. and LIII. of the *Memoirs* have been published during the year.

Vol. LII. consists entirely of "Observations of twenty-three Variable Stars" by the late Mr. George Knott, and was edited by Professor H. H. Turner. The Council have pleasure in expressing their indebtedness to Mrs. Knott for her generous contribution towards the expenses of publication of these observations.

Vol. LIII. contains the following papers :—

Observations of the Solar Eclipse, 1896 August 8, by E. J. Stone.

Micrometrical measures of Double Stars, by W. Coleman.

Theory of the Motion of the Moon, chapters i–v., by Ernest W. Brown.

Determination of Terrestrial Longitudes by Photography, by Capt. E. H. Hills.

New values of the division errors of the Greenwich Transit Circle, by F. W. Dyson and W. G. Thackeray.

General Catalogue of the Radiant Points of Meteoric Showers, by W. F. Denning.

Double Star observations, 1895–98, by W. H. Maw.

Supplementary Library Catalogue.

A supplementary catalogue of the Library has been prepared by the Assistant Secretary, which is now in the press, and will shortly be in the hands of the Fellows.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows during the past year :—

Lieut. C. W. Baillie.
Rev. E. L. Berthon.
James Carpenter.
Samuel Cooke.
Thomas Finch.
N. E. Green.
John Marshall.
B. T. Moore.
John Newton.
G. C. Pulsford.
J. C. Roger.
Rev. John Slatter.
Hale Wortham.

The Council have received notice of the death of Thomas Finch, which occurred in 1896.

CHARLES WILLIAM BAILLIE was born at Greenwich 1844 June 26, and was the son of the late Henry Robert Baillie, of Queen's Home, Greenwich Hospital, and grandson of the late Jonathan Baillie, Paymaster R.N. He entered the Navy in 1859, obtained his commission as navigating sub-lieutenant in 1864, and was promoted to navigating lieutenant in 1870. He was detailed on surveying duties in various parts of the world, and in 1870 he became a first-class assistant surveyor. Whilst he was on the North American station, about 1871, he invented his sounding machine, which is still in use. It is a modification of the apparatus known as the "Hydra" machine, so named because it was constructed by the blacksmith on H.M.S. *Hydra*. It was used in the *Challenger* expedition, and is described in Sir Wyville Thomson's *Cruise of H.M.S. "Challenger."* Whilst Lieutenant Baillie was surveying on the China station on board the *Sylvia*, under Captain (now Vice-Admiral) St. John, he was appointed Director of Naval Studies at the Imperial Naval College at Tokio, Japan, an office which he held during the years 1873–79. It was probably in these years that he picked up the ancient Japanese works on Astronomy, which he presented in 1894 to the Society. In 1879 he was placed on the retired list, and became Assistant Marine Superintendent at the Meteorological

Office; on the retirement of Captain Toynbee in 1888, he succeeded him as Marine Superintendent. The principal works which he has carried out in that capacity have been the charts of sea surface temperature, of barometrical pressure, and of currents for all oceans. The discussion of the meteorology of the South Indian Ocean from the Cape of Good Hope to New Zealand, which is shortly about to appear, has been carried out under Lieutenant Baillie's superintendence, while he had laid down the lines of inquiry to be pursued in the work now in hand at the office—the *Meteorology of the South Atlantic and of the Coasts of South America.*

Lieutenant Baillie married in 1867 Helen, daughter of A. M. Conyers, of Bermuda. He died suddenly at Broadstairs, 1899 June 24, at the age of fifty-five years, leaving a widow and seven children.

He was elected a Fellow of this Society 1879 January 10.

The Rev. Edward Lyon Berthon was born in Finsbury Square, London, 1813 February 20. His father, Peter Berthon, was a descendant of St. Pol le Berthon, only son of the Huguenot Marquis de Chatellérault, who survived the massacre that followed the revocation of the Edict of Nantes in A.D. 1685, and escaped to Bordeaux, thence to Lisbon, where he engaged in trade as a merchant, and had contracts for supplying the Army with provisions during all the campaigns in the Peninsula. His mother was a daughter of the great surgeon, Henry Park, of Liverpool.

When only five years of age he was adopted by his grandmother, who resided at Leyton, in Essex; and he was sent to private schools at Walthamstow and Woodford until he was nearly fourteen years of age. About this time his grandfather, Henry Park, was retiring after a very successful practice of sixty years, making over the same to a Mr. James Dawson, on the understanding that it was eventually to come into the possession of his grandson. Accordingly Edward Lyon went in 1828 to Liverpool, where, during a period of five years, he spent the greater part of every day at the principal hospital, under James Dawson, who was then chief surgeon of that institution. He early showed a strong predilection for mechanical science. He had stood by George Stephenson when he started the "Rocket" on the first mile of railway at Rainhill, aud now would seize every opportunity of getting to the Phœnix Foundry, in which two of his brothers-in-law were partners, and where, encouraged in his attempts, he was told that "he was much too good for a doctor, and that he ought to be an engineer." However, after five years' study at Liverpool, he went to Dublin, and completed his medical course at the College of Surgeons in that city.

In 1834 he married Margaret, youngest daughter of William Preston, Esq., of Birchfield and Fairview, Toxteth Park, Liverpool, by whom he had two sons and five daughters. One son and four daughters survive him. Mrs. Berthon died in 1865.

After his marriage Mr. Berthon spent considerable time both in home and continental travel, and in 1841 he determined to take Holy Orders. He had, three years previously, entered his name at Emmanuel College, Cambridge, but migrated to Magdalene, where he entered as a Fellow Commoner. He took his degree in 1845, and, having been ordained deacon, was licensed to the curacy of Lymington, in Hampshire. In 1846 he was ordained priest, and in the following year was presented to the living of Holy Trinity, Fareham, in the same county.

It was during his residence at Fareham—a country town then largely the abode of retired naval officers—that he conceived the idea of his collapsible boat. This invention, which has made his name famous, was suggested by the wreck of the s.s. *Orion* off the coast of Portpatrick, 1849 June 29. He also at this time perfected his "speed indicator" or "perpetual log" for ships, which was fitted to the then new royal yacht *Victoria and Albert*; also to the *Osborne*. In or about 1858 he resigned his living, as he said, "to get away from ships and boats." In 1860 he became Vicar of Romsey, Hants, which he held for thirty-two years, retiring in 1892.

About twenty-seven years ago (1873), at the earnest solicitation of the late Samuel Plimsoll, M.P., the collapsible boat was revived. Another start was made. Fortune favoured the enterprise; large orders came in from our own and the German Governments; and under the style and title of the "Berthon Boat Co., Ltd.," with Mr. Berthon as constructing director, and his son, E. P. Berthon, as manager, it soon became a thriving industry, employing nearly one hundred workmen. Mr. Berthon gave a lecture in this connection at the Royal United Service Institution so recently as 1895, his subject being "Collapsible Boats and Pontoons for Military Purposes." Mr. Berthon was among those who in early days foresaw the future of the screw propeller for ships (1835), but, through many discouragements, he abandoned a patent which he had taken out. He was told that the screw was "a pretty toy which never would and never could propel a ship." He had only to wait until the close of the Crimean war to see, as he would say, "every line of battleship, every frigate, sloop of war, floating battery, and gunboat *with the screw.*" He also invented the "Nautachometer," or speed indicator; the clinometer, or trim indicator; roll and draft indicator; drogue, or sea-anchor; collapsible pontoons, portable hospitals, tents, &c. Mr. Berthon was, in short, a man of wonderful versatility. As a preacher he was eloquent, as a lecturer bright and entertaining. Moreover, he had a great charm of speech, and was master of three or four languages. Theology, architecture, philosophy, mechanics, sculpture, and art, in all he excelled, and many are the traces of his handiwork, in cunningly carved and leafy boss, in gilt pateræ, and sacred symbol, to be found in the grand old Norman Abbey Church at Romsey, where, notwithstanding his retirement, he did frequent duty, and was to the

last the authority to whom all referred in matters connected with the restoration of that noble fabric.

He designed the well-known "Romsey Observatory"; two or three equatorial stands for reflecting and refracting telescopes, one of which—a 12½-inch reflector—received a silver medal at the Paris Exhibition, 1878. His "dynamometer" for ascertaining the power of eyepieces is well known, though not so much so his latest proposal—of only last year—for standardising eyepieces. Many telescopes were constructed by him of different apertures—the specula, the writer believes, excepted—including a reflector of 18 inches, and weighing nearly two tons, for the late Rev. H. Cooper-Key; a 10·5-inch equatorial for the late Professor Pritchard of Oxford, and a stand for that "keen observer of the starry host" and author of *Celestial Objects*, the Rev. Thomas Webb, of Hardwick Vicarage, Hereford. And of work in other directions, "it is a pleasure," said he, "to reflect that I have enabled many a brother priest of limited means to rejoice in the possession of an equatorial telescope of from nine to eighteen inches aperture, and thus to pursue the most noble of the physical sciences, and to sing intelligently with the Psalmist, 'Cœli enarrant gloriam Dei.'"

In the autumn of 1898 Mr. Berthon finished an equatorial of sixteen and a half inches aperture (speculum by Sir Howard Grubb) and nearly ten feet focal length, together with an observatory, constructed at the Boat Works, Romsey, for a gentleman at Johannesburg.

Mr. Berthon was elected a Fellow of this Society 1865 January 8, and retired in 1880. He had one paper in the *Monthly Notices*—"On the Equestrian Equatorial" (*M.N.* vol. xxxv. p. 106). It was read at the meeting 1874 December 11, when he exhibited the instrument. He was re-elected 1899 May 12, and many will remember the ovation he received when, on his re-admission 1899 June 9, he exhibited two telescopes of his construction, together with a simple device for dividing telescope circles.

Mr. Berthon died at his residence, St. Margaret's, Cupernham, Romsey, 1899 October 28.

[For the above particulars the Council is indebted to Mr. J. J. Hall, of Slough.]

James Carpenter was born at Greenwich in the year 1840. He entered the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, as computer, in the year 1854, being after a time transferred in a similar capacity to the Astronomical Department, in which, on the retirement of Mr. H. Breen, in 1859, he was appointed assistant. At this time the new South East Equatorial was approaching completion, and in 1861 it was placed under his special charge. He was a good draughtsman, and, in addition to his ordinary astronomical duties, made from time to time drawings of the planets *Mars*, *Jupiter*,

and *Saturn*, one also of the nebula in Orion, some of the lunar crater *Linné* (then suspected of having changed its form), as well as drawings of various comets, including some excellent pictures of Donati's comet (1858) and of the Comet II., 1861 (the great comet of the summer of that year). In the year 1863 he measured the positions of lines in the spectra of numerous stars with the instrument designed by Sir George Airy. He had the continuous charge of the library and manuscripts of the Observatory, and prepared an entirely new catalogue, on the slip system, of the books of the former. He was elected a Fellow of the Society 1867 February 8. In 1870, at the request of Sir William Huggins, and with the consent of the Astronomer Royal and the Admiralty, he went to Oran, in Algeria, to observe the total solar eclipse of December 22 of that year, but the circumstances of weather were unfortunately unfavourable. In 1871 he carried out, under the direction of the Astronomer Royal, a series of experiments for determining the distribution of magnetism in bar magnets and in galvanic coils, and in 1872 was deputed, in conjunction with Captain Tupman, R.M.A., to make an examination into the magnetic condition of the Britannia and Conway tubular iron bridges, the results of these experiments being contained in two papers contributed by Sir George Airy to the Royal Society in the year 1872. In the same year Mr. Carpenter resigned his position at the Royal Observatory to enter the service of John Penn & Sons, marine engineers. He had previously married Ellen Penn, the daughter of the late Mr. Thomas Penn of the same firm. After holding the position mentioned for eighteen years, he was led to retire therefrom on account of the ill health of his wife, who died soon afterwards at Hastings. Mr. Carpenter survived her for nine years, during the later portion of which he suffered from an affection of the heart, from which he died, 1899 October 17, at the age of fifty nine, at Grove House, Lewisham, leaving no family.

It should be mentioned that Mr. Carpenter worked as collaborator with Mr. James Nasmyth, the engineer, in the preparation of their joint work on "The Moon," of which several editions were issued. The authors remark that much labour had been bestowed upon the topography of the Moon, and sufficient written for those who desire acquaintance with the intricate movements of the Moon in space, but that little attention had been given to the Moon's physiography, to the causes of the features, broad and detailed, that our satellite presents. From carefully made drawings of many different portions of the Moon's surface, again and again revised and compared with the actual objects, the authors constructed models which, when placed in the Sun's rays so as faithfully to reproduce the lunar effects of light and shadow, were photographed, thus obtaining pictures representing in a striking manner the details of the lunar surface. In the accompanying text these features of the Moon are described, and the views of the authors as to their formation explained.

Mr. Carpenter was a ready writer, and contributed numerous articles on a variety of subjects, mainly scientific, to the current periodicals of the time; his expositions of phenomena were couched in a style that was not only in itself attractive, but also conveyed to the reader such accurate information as would enable him clearly to understand the various matters treated. He had also a very practical turn of mind, was a good mechanic, had artistic tastes and musical ability, and was moreover an excellent photographer, and in the later years of his life he gave great assistance, in conjunction with Dr. Moore, in the installation and practical application of the Röntgen ray method to surgical purposes at the Miller Hospital, Greenwich, of which Institution he was a Member of Committee. W. E.

Samuel Cooke was born 1844 May 22. He was educated at Trinity College, Dublin; and, having completed the course in the School of Engineering, he took his degree in 1868, receiving two special certificates in Mechanical and Physical Science, and in Chemistry, Geology, and Mining. Immediately after taking his degree, he was appointed to be Professor of Chemistry and Geology in the Civil Engineering College at Poona, University of Bombay. His father, Mr. Theodore Cooke, was at the time Principal of the College; and on his retirement in 1893, after holding the office of Principal for twenty-eight years, the son, Mr. Samuel Cooke, was appointed Principal of the College of Science, as it was then called, in his stead. Mr. Cooke was the author of several text-books, which have run through many editions; amongst others may be mentioned his *First Principles of Chemistry* (six editions), *Students' Practical Chemistry* (three editions), *First Principles of Astronomy* (five editions), *The Foundations of Scientific Agriculture*, published in 1897.

He was elected a Fellow of this Society in 1898 February 11.

Nathaniel Everett Green was born at Bristol 1823 August 21. He was the third son of Benjamin Holder Green, of that city, and bore his mother's maiden name. She was Elizabeth Everett, of Crokerton, Wilts. He was educated chiefly by his uncle, the Rev. C. Everett, and in 1840 started life in a merchant's office in Liverpool. Finding a commercial life uncongenial to him, and having a great taste for drawing, he decided to adopt art as his profession, and came to London in 1844, entering the Royal Academy as a student in December of that year. Here he worked side by side with Leighton, Millais, and Rossetti. In 1847 he married Elizabeth Goold, of Cork, and after living for about a year in the west of London he eventually settled in St. John's Wood, where he resided for forty-nine years, attracted to the neighbourhood by its quiet retirement and its favourable surroundings for the pursuit of his artistic and astronomical studies. He frequently exhibited his work, both in oil and water colours, at the Royal Academy and other galleries, but the

pressing needs of a large and growing family—he had five daughters and four sons—led him to adopt teaching as a profession. In this he was eminently successful, and gained a widespread reputation. In 1880 he was called to Balmoral, and had the honour of numbering amongst his pupils Her Majesty the Queen, the Princess of Wales, and Princess Beatrice. He was the author of many works on art, principally manuals and other works of a practical kind, which have had a wide circulation.

In 1884 he visited Palestine, and there some of his best water-colour drawings were made. A succession of dreary winters in London drove him in 1890 to seek summer skies for his artistic work, and for this cause, as well as for the benefit of his wife's health, he selected Cannes as his winter home. During the six seasons spent there he formed a wide circle of friends, and he continued his work there till his last visit in 1898–99.

His interest in astronomy dates back to 1859, when he constructed a telescope for himself, and began the long series of observations and drawings which he continued to make till within a year and a half of his death. His most numerous drawings were made in the two observatories in his garden in Circus Road, St. John's Wood. He frequently changed his instruments, always striving to get greater perfection, and in his Memoir on Jupiter (*Memoirs R.A.S.*, vol. xlix.) he speaks of having used five different instruments in his observations during the years 1859–87—namely, successively "a 4-inch and a 5-inch refractor, and reflectors of 9, 13 and 18 inches, the last a superb mirror figured by George With, of Hereford." In 1877, on the occasion of the favourable opposition of *Mars*, Mr. Green went to Madeira, and during August and September he made the series of admirable drawings of the planet with which his name will always be associated. Of the forty one sketches made with a 13-inch With reflector, twelve were reproduced in his Memoir (*Memoirs R.A.S.*, vol. xliv.), as well as enlarged drawings of the south polar cap and a map of the planet. Of these drawings Professor Keeler has said in his Memoir (*Memoirs R.A.S.*, vol. li.): "The admirable drawings of Mr. Green owe much of their value to the care which has been bestowed on the appearance of the different features, and their general agreement with views of *Mars* in both large and small telescopes is doubtless due to the same reason. It seems to me that the habit of representing indefinite boundaries by sharp lines and neglect to preserve a uniform scale of relative intensity are responsible for most of the discrepancies in drawings which are ascribed to personality of the observer in interpreting faint markings." It is interesting to note that Mr. Green's observations were made with a 13-inch reflector, and Professor Keeler's with the 13-inch refractor of the Allegheny observatory.

At the less favourable opposition of *Mars* in 1886, Mr. Green made further studies of the planet, and made a map of the northern hemisphere. These were not published, but several of

the sketches and a map of the planet constructed from them are in the rooms of the Society.

In the *Monthly Notices* of the Society six short papers by Mr. Green are published relating to observations of *Mars* and *Saturn*. And the *Memoirs* of the Society contain two papers by him; the first in vol. xliv., already referred to as containing the results of his observations of *Mars* in 1877; the other, in vol. xlix., giving the results of a series of observations of *Jupiter* during the years 1859–87, and illustrated by a series of beautiful drawings.

In the Journal of the Selenographical Society Mr. Green has given proof of his active membership in a long series of papers on Lunar formations, accompanied by drawings.

Mr. Green was a member of the Provisional Committee of the British Astronomical Association, and was President of the Association in 1897–98. In 1896 he joined the Eclipse expedition to Norway, and it is much to be regretted that he had not the opportunity of using his skill in the delineation of the corona. He was a type of the best kind of amateur observer. Possessing great skill in drawing, he devoted himself to observations in which his keen sight and true hand enabled him to secure results of permanent value. He was always ready to put his experience at the disposal of other observers, a fact which is exemplified both in the character of his notes, already referred to, in the Monthly Notices and in the admirable practical lecture on astronomical drawing published in the third volume of the *Journal of the British Astronomical Association*.

For a period of nearly forty years he continued his astronomical work with unflagging perseverance. His profession often claimed him the whole day long, and after a light meal he would begin work with the telescope, often prolonging his study far into the night. On unfavourable evenings he would devote himself with equal assiduity to work with the microscope.

Besides his published drawings, Mr. Green left behind him a great number of sketches of detail on the Moon, of *Saturn* and of *Mars*, and a long series of drawings of *Jupiter*.

He was elected a Fellow of the Society 1875 February 12. He died after a very short illness, 1899 November 10, at the age of seventy-six, leaving a widow.

[For most of the particulars in this notice the Council is indebted to his daughter, Miss Green.]

John Marshall was born at Leeds 1825 April 11, and was the son of Thomas Marshall. He got a training in lithography, and was for some years the manager of one of the large printing works in Leeds. Whilst he was engaged in lithography he drew upon stone facsimiles of many letters of eminent writers, and they were printed on a large sheet. A bronze medal was awarded to him for this holograph sheet at the Leeds Exhibition of 1858. For twenty-two years Mr. Marshall was Secre-

tary and Librarian to the Leeds Church Institute, and retired from this post in 1897 in consequence of ill health. He was an active Freemason, and was a fellow of several of the learned societies.

He was twice married, first in 1846 and again in 1863. By each marriage there were five children. He died in 1899 January 21, leaving a widow and three sons and two daughters.

He was elected a Fellow of this Society 1879 February 14.

[For the above particulars the Council is indebted to his son, Mr. G. H. Marshall, of Leeds.]

Benjamin Theophilus Moore was born 1830 January 3. He went to Cambridge in 1851, entering Pembroke College, and graduated in 1856 as eighth wrangler. He was soon afterwards elected a Fellow of his College, and retained his fellowship until 1866. On leaving Cambridge in 1856 Mr. Moore became Mathematical Master of the Army Class at Harrow, and in 1859 he was appointed Professor of Mathematics at the Royal Staff College, Sandhurst, where he remained for five years. Among his pupils in those years may be mentioned Sir W. Palliser and the late General Colley. For several years after 1864 Mr. Moore was occupied in Civil Engineering, and in 1868 he was elected Professor of Civil Engineering and Applied Mechanics in University College, London, a post which he held until the session 1870–71.

In private life Mr. Moore's greatest pleasure was the study of astronomy; he possessed a fine telescope (7-inch object glass) and observatory.

Mr. Moore married in 1872 Margaret Jane, third daughter of Charles John Wood, Esq., J.P., of Glastonbury, Somerset, late of St. Petersburg. He died 1899 November 15, and leaves a widow and five daughters and one son.

He was elected a Fellow of this Society 1893 June 9.

John Newton was born at Wickham, Hants, 1832 December 27. He was educated at the Greenwich Hospital Schools under Mr. Edward and Mr. John Riddle, and in 1854 he became a teacher of Navigation and Nautical Astronomy at the Board of Trade Navigation Schools at Leith, and later at Glasgow, and at the Sailors' Home, London. For many years, up to a short time before his death, he conducted a school of his own very successfully. His publications *Newton's Seamanship* and *Newton's Guide to Board of Trade Examinations* were very popular, and passed through many editions.

He was elected a Fellow of this Society 1862 May 9, and died at New Cross 1899 November 10.

[For the above particulars the Council is indebted to his son, Mr. L. B. Newton, of New Cross.]

Charles Leeson Prince was born at Uckfield, Sussex, 1821 June 15, where he passed the greater portion of his life;

and he died 1899 April 22 at his residence, The Observatory, Crowborough, in the same county, and but seven miles distant from his birthplace.

His father, Charles Prince, originally of Cambridgeshire, settled in Sussex and practised as a medical man in Uckfield and the surrounding districts. From Uckfield to Tunbridge Wells *viâ* Crowborough, a ride of fourteen miles, was a common professional round in the early part of the century now closing, and Mr. Prince would often relate how his uncle, his father, and another doctor used to meet at Crowborough—then a bare hill-top and not considered safe, being frequented by highwaymen—who on seeing Charles Prince would pounce out and say, "Oh! it's the doctor; let him go."

Through his mother, Mary Ann (*née* Boys), Mr. Prince could trace his ancestry to Dean Boys, whose monument may be seen in Canterbury Cathedral.

He was educated primarily at the Uckfield Grammar School, under the Rev. John Underwood, and subsequently at Lewes, and received his medical training at Guy's Hospital like his father before him; and so became the fifth surgeon in the family by direct descent from father to son. He settled at Uckfield, and practised with his father till the death of the latter, after which he remained in the same place till 1872, when he removed to Crowborough, at that time a barren common, but now, largely through Mr. Prince's influence, a health resort of no small repute. As a physician Mr. Prince paid special attention to the treatment of both epilepsy and hydrophobia. In the British Medical Association's *Journal* of 1874 May 16 appeared an account of his treatment of the latter disease.

Mr. Prince became a member of the Royal College of Surgeons in 1843; he was also Licentiate of the Society of Apothecaries; Fellow of the Royal Astronomical Society (elected 1857); Fellow of the Royal Meteorological Society; Member of the British Astronomical Association; Member of the Scottish Meteorological Society; Member of the Selborne Society; Vice-President of the Tonbridge Wells Photographic Society; and Member of Council of the Sussex Archæological Society.

He was a man of many parts; up to his last illness he took a keen and active interest in such widely diverse pursuits as medicine and surgery (though he had retired from practice some ten years), astronomy, meteorology, photography, botany (which he studied practically in his beautiful gardens at Crowborough), archæology and numismatics.

Furthermore he had a very fine library, containing some rare and valuable books, some of the more famous editions of the Bible, and the earliest printed copies of the classics.*

* It will be remembered that in 1898 Mr. Prince presented to the Society a number of very valuable books from his library, including, among others, no less than eight editions of Aratus and three of Manilius.

He was the inventor of "Prince's Perpetual Calendar," by which the day of the week on any date past or future may be found through an arrangement of the Sunday letters. Of this calendar he caused a silver casting to be made, which he left as an heirloom to his infant grandson, Christopher Switzer.

He studied photography practically from the cradle of that science, and has left on record descriptions of many early examples now difficult to procure, and he had a unique collection of old paper negatives dating from the forties. His coins also formed a most interesting collection, well worth studying. His bookplate was a very beautiful production, and may be found in an early number of "Ex Libris."

In 1882 he issued *The Illustrated Account given by Hevelius in his "Machina Celestis" of the Method of Mounting his Telescopes and erecting an Observatory.* This work consists of a reprint of Chapters xviii., xxi., and xxii. from an original copy of Hevelius, together with a translation and some remarks.

In 1883 he published his *Observations upon the Great Comet and Transit of Venus, made at Crowborough, Sussex, in the year* 1882. With illustrations.

And in 1895 he brought out *A Literal Translation of the Astronomy and Meteorology of Aratus, with some Bibliographical Remarks.* With regard to illustrations, Mr. Prince says in the preface to this work: "As a frontispiece to this little volume I have given a representation of the revolution of the planets around their supposed primary, in the order designed to them by the Ancients in the time of Aratus. This engraving appears first, as far as I know, in the edition of Hugo Grotius, publisher at Leyden, in the year 1600; while Cellarius, in his *Harmonia Macrocosmica*, 1661, has given the same on a much larger scale, and it is from this latter plate that I have taken a photograph."

Mr. Prince contributed to the *Monthly Notices* of the Royal Astronomical Society papers on cometary, stellar, and other observations. "He studied the details of the course of discovery in the nature of *Saturn's* ring system, and took part in investigations initiated by Mr. Lynn, which resulted in showing that Cassini and not Ball was the first to detect the principal division in the ring." (See *The Observatory*, 1899 June, pp. 243–4.)

Mr. Prince had several telescopes and other instruments at his observatory which he greatly prized; the chief was an equatorial with an object glass of 6·8 inches aperture and 12 feet focal length, which had formerly belonged to Dr. Pearson, and was originally made by Tulley, about the year 1823 (vide *Memoirs R.A.S.*, vol. ii. p. 507).

His chief contributions to the science of meteorology were his two books on *The Climate of Uckfield and its Neighbourhood*, published in 1871, with a second edition in 1886, and his *Observations upon the Topography and Climate of Crowborough Hill, Sussex*, the second edition of which appeared in 1898, not twelve months before his decease. For more than forty years Mr.

Prince assiduously carried on an unbroken series of meteorological observations.

He married in 1865 Jessie, daughter of the late William Brass, of Clifton, Bristol, and Reigate, who survives him, as likewise do his three children, Ada Charlotte (married to the Rev. B. N. Switzer, M.A., of Hitchin, Herts), William Leeson, and Evelyn.

Mr. Prince's illness became acute in 1898 November, and he underwent a considerable amount of suffering till finally released by his death in 1899 April.

He was buried in Uckfield Churchyard.

[For the above notice the Council is indebted to his son-in-law, the Rev. B. N. Switzer, M.A., of Hitchin.]

George Carter Pulsford was born at Lyme Regis, Dorset, 1842 November 4. He entered the Royal Hospital School, Greenwich, as a pupil in the Upper School in 1852, and thus came first under the care of Dr. Hill, and afterwards studied navigation and astronomy under Mr. John Riddle. At the termination of his school term he was retained as pupil teacher until 1861, when he became Mathematical and Navigation Master on the *Conway* at Liverpool. He, however, remained there but two years, being recalled to his old school as Master in 1863. When in 1874 the Lords Commissioners of the Admiralty decided on educating Naval School Masters at Greenwich, instead of sending them, as formerly, to the Normal Training Colleges, Mr. Pulsford was associated with the Headmaster, Mr. A. Escott, in their training. Finally, on the death of the latter, he succeeded to the Headmastership. Although his special work separated him in a measure from other schools, he always exhibited great interest in educational movements, and was for some time Secretary of the West Kent branch of the Teachers' Guild of Great Britain and Ireland. He was an active Freemason, and was held in high esteem by members of that body. At the time of his death, which occurred on August 1, he was spending his summer vacation at Salcombe.

He was elected a Fellow of this Society 1894 May 11.

T. L.

James Cruikshank Roger was born at Dundee, 1820 May 21. He was the second son of the late Charles Roger, of Dundee, and was educated at Glasgow University. He resided at Glasgow for some years, and in 1848 married Margaret Chalmers, youngest daughter of Francis Neilson, a physician of that city. Inheriting the literary tastes of his father, he devoted a great deal of his leisure to antiquarian pursuits. During the years 1869–70 he was editor of the *Antiquary*. Heraldry was also a favourite subject with him, and he was the author of *Summary of Moral Evidences*. In one of his earliest works, *Celticism, a Myth*, he upheld the Scandinavian origin of

the British races. After the death of his wife in 1861 he went to London, and entering as a student of the Middle Temple in 1868, he was called to the Bar in 1871. He was a man of considerable energy of character, and for some time was Captain in the 48th Middlesex Rifle Volunteers. He died after three days' illness of acute pneumonia, at his residence, Friars Watch, Walthamstow. His second wife survives him.

He was elected a Fellow of this Society 1887 January 14.

John Slatter was born at Iffley, near Oxford, 1817 April 9. He went up to Oxford in 1835, and entering at Lincoln College, he became one of Lord Crewe's Exhibitioners and graduated in 1838, taking a third class in Lit. Hum. and a first class in mathematics. In 1841 he took his M.A. degree and was ordained. For some years he worked at Leeds under Dr. Hook, the Vicar of Leeds. He then had charge of Sandford-on-Thames, near Oxford, during the years 1852–61, residing at Iffley. In 1861 he was appointed Vicar of Streatley, Berks, and in 1880 Rector of Whitchurch, Oxon., where he remained until the time of his death, 1899 April 7. He had a private observatory at Rose Hill, Iffley, where he worked a good deal. He was obliged to give this up when he went to Streatley, but he still kept up much interest in astronomy. He was elected a Fellow of the Society 1847 November 12, and communicated two short notes to the *Monthly Notices*, one (in *Monthly Notices*, vol. xxxii. p. 317) relating to the observations of the Aurora of 1872 February 4, and containing some interesting remarks as to the height of the Aurora as deduced from observations of an auroral arch made at Streatley simultaneously with observations at Greenwich, 1870 October 24. Mr. Slatter deduced a height of 118 miles above the Earth's surface, on the assumption that the same phenomenon was observed at both places. He mentions one other case, in which the identity of the phenomenon observed was satisfactorily established, and in this case with a base of nineteen miles a height of less than three miles was deduced.

He married Elizabeth, daughter of Richard Wootten, Esq., of Iffley, and had one daughter.

Hale Wortham was born at Royston, 1822 July, and was the son of the late Thomas Wortham, solicitor, of Royston. He was educated at Mr. Carver's school at Melbourn, Cambs, and King's College, London. In 1844 he was admitted to practice, and on the death of his father, which occurred shortly afterwards, he succeeded to his business, living alone at Royston. In 1871 December he was appointed Clerk of the Peace for the County of Cambridge, in place of Mr. H. R. Evans, of Ely. When the Local Government Act came into operation in 1888, and many of the functions discharged by Quarter Sessions were transferred to another authority, an enormous amount of work devolved upon Mr. Wortham. He was appointed Clerk to the newly constituted

County Council, and occupied that post until his death. He was also Clerk to the Magistrates of the Arrington and Melbourn Division, and of the Odsey (Hertford) Division; and was a Deputy-Lieutenant for Cambridgeshire. Mr. Wortham owned considerable property in Royston, where he had lived all his life. He died, after a short illness, 1899 April 18.

He was elected a Fellow of this Society 1856 March 14.

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 12,104 observations of transits and 11,088 of zenith distances were made in 1899, about 3000 of these observations having been made below pole.

The total number of stars observed is about 5000, about 1400 of these being within 10° of the pole.

The Sun was observed 204 times with the transit circle, its horizontal diameter 162 times, and its vertical diameter 179 times.

The Moon was observed 130 times ; the mean errors in R.A. of Hansen's Lunar Tables with Newcomb's corrections is $-0^{s}\cdot101$. The errors since 1883, when Newcomb's corrections to Hansen's tables were introduced into the *Nautical Almanac*, are as follows :—

	s		s		s
1883	+0·031	1889	+0·010	1895	−0·066
1884	+0·018	1890	+0·020	1896	−0·088
1885	+0·024	1891	+0·079	1897	−0·154
1886	+0·029	1892	+0·083	1898	−0·160
1887	+0·059	1893	+0·034	1899	−0·101
1888	+0·090	1894	−0·016		

The R−D discordance, which had become very small in 1897 and 1898, shows an increase in 1899, the correction to direct observations found for last year being $+0''\cdot08+0''\cdot22$ sin Z.D. The special observations of pairs of stars directly and by reflection, which have been made for the four years 1895, 1896, 1897, and 1898, show a satisfactory agreement with the ordinary observations reflection and direct at the same transit, confirming the striking diminution in the value of the R−D discordance in 1897 and 1898 as compared with 1895 and 1896. It results, therefore, that the R−D discordance is not in any way due to the circumstance that the direct observation is taken immediately after the reflection observation.

The Second Ten-Year Catalogue of 6892 stars for 1890, from observations made in the years 1887–1896, is in the press, the first fifteen hours being already printed. The catalogue consists largely of fundamental stars and of stars from Groombridge's Catalogue of 4243 circumpolar stars, epoch 1810, of which about 3600 have been observed. About 2000 stars in the catalogue have been observed above and below pole, so that the catalogue contains considerable material for discussion of latitude and refraction.

Comparisons have been made between this catalogue and the fundamental catalogues of Professor Newcomb and Dr. Auwers, the Greenwich Ten-Year Catalogue for 1880, the Cape Catalogue for 1890, the Zone Catalogues of the *Astronomische Gesellschaft*, the Radcliffe Catalogue (1845), and Groombridge's Catalogue (1810).

The re-observation of the stars of Groombridge's Catalogue, which was the principal object of the Second Ten-Year Catalogue, furnishes material for determination of the proper motions of more than 4000 stars from observations about eighty years apart, with intermediate positions in the Radcliffe Catalogue of 1845. For use in the Second Ten-Year Catalogue, provisional proper motions have been determined for 163 stars, for which the proper motion in R.A. or N.P.D. amounted to 0″·1 in arc of a great circle, and had not previously been determined. It is proposed now to undertake the determination of the proper motions of all the Groombridge stars; but before doing this it is advisable that Groombridge's observations should be re-examined in view of the large systematic errors in R.A., apparently due to faulty determination of azimuth error.

The Altazimuth.—This instrument has required a good deal of attention during the year. In January several of the screws attaching the telescope to the axis were found to be loose, and bolts were substituted. At the same time the attachment of the eye-end to the tube was strengthened and the object glass was re-centred.

On June 21, and again on October 31, one of the pivots fired and had to be re-ground. On the latter occasion new Y's made of bell-metal were substituted for cast iron. On September 3 the object glass was found to be loose, and was fixed firmly.

During the year 1719 transits and 1492 zenith distances were observed in the meridian. The Moon was observed 21 times in right ascension and 24 times in zenith distance on the meridian, and 9 times in other azimuths. The errors of the microscope screws have been determined, and found to be small, and in order to eliminate as far as possible the effect of wear in the future, the screws have been reversed and the heads re-figured in the opposite direction for one of each pair of opposite microscopes.

In November a double pair of webs, about $4\frac{1}{2}'$ apart, were inserted in each microscope, so that two divisions of the circle

may be read to give the correction for runs, and eliminate any "drunkenness" of the screw.

A re-determination of the division errors of each degree of the fixed and movable circle by a symmetrical process was begun in December, and has just been completed.

28-*inch Refractor*.—Measures of distance and position-angle have been made of 556 double stars, each star being observed on the average on 2·3 nights. Of these, 134 are less than 0″·5 apart, 131 between 0″·5 and 1″·0, 92 between 1″·0 and 1″·5, 40 between 1″·5 and 2″·0, and 159 over 2″.

Among the stars the following interesting pairs, which were measured several times, may be mentioned :—

	Mags.	Dist.	No. of Nights.		Mags.	Dist.	No. of Nights.
		″				″	
Aldebaran	1, 14	31·1	3	Σ 2525	7½, 7½	0·3	9
β 883	7½, 7½	0·3	8	γ² Androm.	5, 6	0·3	9
ζ Herculis	3, 6	0·5	12	ε Hydr. A.B.	3½, 7½	0·2	4
70 Ophiuchi	4, 6	1·6	11	Σ 1639	6½, 8	0·2	4
κ Pegasi	4, 5	0·3	11	OΣ 225 A.B.	8, 11	0·7	4
β 151	4½, 6	0·6	9	99 Herc.	6, 11	0·9	3

Thirty-six occultations of stars by the Moon have been observed during the year by one or more observers, 28 of them occurring during the lunar eclipse of December 16.

Thompson Equatorial.—A number of improvements in detail have been made in the instrument during the year. The driving of the telescope has been much improved by the attachment of a weight to the sector, which keeps it constantly bearing on one side, and by the substitution of an astronomical clock with zinc and steel pendulum for a wood rod pendulum for the electric control. The Hodgson 6-inch refractor, the guiding telescope of the 30-inch reflector, has been fitted with scales at right angles and mounted more firmly. An occulting shutter has been arranged for use with the 26-inch refractor in the photography of bright stars with faint companions.

With the refractor 224 photographs have been taken. These include 34 of *Neptune* and its satellite, of which 16 photographs taken on 15 nights have been measured; 21 of Comet *a* 1899 (Swift), of which 15 taken on 14 nights have been measured; 120 of 44 double stars, of which 58 of 25 stars have been measured; and 9 for parallax.

With the reflector 79 photographs have been taken. These include 41 of *Eros*, of which 32 taken on 24 nights have been measured, one of Comet *b* 1899 (Tuttle), and photographs of the *Pleiades* and of the *Orion* nebula at the principal focus.

Experimental photographs have been taken with the spectroscope of the Solar Spectrum, and of *a Lyræ* and *a Cygni*. Some additions have been made to the spectroscope in detail, of which

the most important are the arrangements for guiding on the slit according to the method of Sir W. Huggins.

With the astrographic equatorial 539 plates with 1025 exposures have been taken on 125 nights. Of these, 149 have been rejected—viz. 17 because the exposure was interrupted by cloud, 23 because the photographs did not come up to the standard in showing faint stars, 28 owing to bad guiding or wrong setting, 20 owing to imperfect printing of the reticule, 36 owing to defects in the photographic plates, and 25 from miscellaneous defects. The number of rejections is unusually large; 15 of the imperfectly printed reticules occurred in August through a temporary difficulty with the electric light; 35 of the defective plates occurred in a batch near the end of October. Of the 390 successful plates, 201 are for the chart, 171 for the catalogue, 7 are photographs of standard areas, and 11 are for the adjustment of the equatorial.

The following table shows the progress of the photo-mapping of the heavens to the end of 1899:—

	Catalogue.	Chart.
Number of successful fields on 1898 Dec. 31	971	923
" " " " taken in 1899	171	201
Number previously passed rejected in 1899	92	62
Number of successful fields, 1899 Dec. 31	1050	1062
Number still required	99	87

Positives on glass of 96 chart plates were made during the year, which, with the 898 reported last year, and striking off 4 rejected since, gives a total in hand of 990.

During the year 1899, 135 plates were measured in the direct and reversed positions; at the date of this report the measurement is completed from 64° to 72° N. decl., with the exception of two plates.

Copy for press of the measures is prepared for zones 68° and 69°, and that for zone 70° is in progress. The measures are printed for zone 64°, and the first sheet of zone 65° is in the printer's hands.

The plate constants and the residuals of the reference stars, derived from the catalogues of the *Astronomische Gesellschaft*, are computed for the plates whose centres are at declinations 65° to 69° inclusive. The catalogue of the Dorpat zone (70° to 75° N. decl.) of the *Astronomische Gesellschaft Catalogue*, which will be required for the plates whose centres are at declinations 70° to 75°, is not yet published; but the director, Dr. Lewitzki, has kindly promised to forward a provisional catalogue in manuscript.

The total number of stars measured in the different zones compared with the number in the *B.D.* and the *A.G.C.* are approximately :—

Zone.	No. of Stars measured on the Plates.	No. in B.D.	No. in A.G.C.
64°	8954	1900	1200 (Helsingfors)
65°	9237	2001	844 (Christiania)
66°	9494	1684	745 ,,
67°	9600	1285	574 ,,
68°	10,200	1429	685 ,,
69°	10,650	1389	646 ,,
70°	11,400	1345	
71°	11,000	1251	
Totals: Decl. 64° to 72°	80,535	12,284	

For the chart plates with forty minutes' exposure arrangements have been made to count the number of stars shown on the areas corresponding to those measured on the catalogue plates. The instrument originally made for measuring the Transit of *Venus* photographs and subsequently modified for astrographic plates has been adapted for counting simultaneously the corresponding star images shown on the overlapping portions of two plates, a hand billiard-marker being used, as suggested by Professor Turner, to facilitate the counting. The number of stars on chart plates has now been counted for rather more than half of the zone 65° to 66° N. declination. We shall thus have available for comparison the number of stars on corresponding areas, shown with exposures of 20^s, 3^m, 6^m, and 40^m on photographic plates and contained in the *Astronomische Gesellschaft* Catalogues and *Bonn Durchmusterung* respectively. The duplex form of measuring instrument specially lends itself to this work, as the stars in any defined area of the sky can readily be counted without overlap, and the simultaneous examination of the images on the two overlapping plates eliminates false stars.

Photographs of the Sun were obtained on 208 days with the Thompson photoheliograph of 9-inch aperture, which is now mounted on the Thompson photographic refractor of 26-inch aperture. Of these, 430 have been selected for preservation, including 14 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1899 September 29, and from Mauritius up to 1899 August 6, leaving only two days for which no photograph is available for measurement in the year ending with the date of the last Indian photograph received.

The Greenwich photographs have been measured in duplicate up to the end of 1899, and the Indian and Mauritius photographs so far as they have been received. The areas and heliographic positions of the spots and faculæ have been computed throughout, and the complete results for 1898 have been printed, and the copy for press for 1899 is ready so far as June 23. The decline

in the solar activity has been very marked during 1899, the number of days without spots having risen from 8 in 1896, 32 in 1897, and 48 in 1898 to 85 in the first nine months of 1899, whilst the mean daily spotted area for 1899 is estimated from the materials at present to hand as only 100 millionths of the Sun's visible hemisphere, as compared with 375 in 1898.

The reduction of the observations made for the longitude of Killorglin, in the West of Ireland, mentioned in last year's report, was completed at the end of May. The publication of the results of the various determinations of longitudes made in the years 1888 to 1898 has now been taken in hand—viz. Paris in 1888, Dunkerque in 1889, Paris in 1892, Montreal, Canso, Waterville in 1892, Killorglin in 1898, and observations at Greenwich at contiguous stations to test the instruments in 1893 to 1897. The copy for press for the 1888 and 1892 Paris longitudes is prepared and will be sent to the printers without delay.

At the desire of the International Geodetic Association arrangements have been made with the Bureau des Longitudes and the Paris Observatory for a re-determination of the longitude of Paris, in view of the discordance between the results found by the French and English observers respectively in 1888 and again in 1892. It is proposed to undertake this re-determination after the publication of the observations made in the previous determinations has afforded an opportunity for full discussion of the results found in 1888 and 1892.

The printing of the annual volume of *Greenwich Observations* for 1897 was completed in November. The Transits, Zenith Distances, Star Ledgers and the Annual Catalogue as far as 15^h, and the whole of the Solar results have been printed for 1898.

The new Observatory building was finally completed last March. Three wings of the ground floor have been fitted with adjustable book-stacks, and the Library has been transferred to them. The books are being rearranged, and it is proposed to make a new card catalogue. The wings of the upper floor have also been fitted up with similar book-stacks for the storage of manuscripts and records and of the stock of Greenwich publications.

Royal Observatory, Cape of Good Hope.

The physical laboratory and the new record room were completed and available for use in July. The latter provides suitable accommodation for the measurement and preservation of astrographic photographs, and both buildings have proved admirably adapted for their purposes.

The contract-dates for delivery of the new transit circle and its observatory have been greatly exceeded, and neither instrument nor observatory has yet been received from the makers.

A chronograph room has been erected near the site of the new transit circle, but the chronograph itself has not been received from Messrs. T. Cooke & Sons.

The 24-inch photographic object glass of the McClean equatorial was returned on October 31, at the request of Sir Howard Grubb, for rectification of faults in the marginal images and in the general chromatic correction.

Part 2, volume ii., of the *Annals of the Cape Observatory*, containing a catalogue of Southern double stars, has been passed through press.

Volume v. of the Cape *Annals*, being the third and last part of the *Cape Photographic Durchmusterung*, has been passed through the press; the work will therefore be very soon ready for distribution.

A summary of the results of the revision of the *C.P.D.*, so far as it has been completed, is contained in the Introduction, but the complete revision, with details of observation of variable stars, investigations of proper motion, complete lists of errata of catalogues compared with the *C.P.D.*, &c., will be published in a subsequent volume of the *Annals*.

A part of volume viii. of the Cape *Annals*, containing "Heliometer Investigations on the Parallaxes of the Principal Fixed Stars of the Southern Hemisphere" is in the press. The remainder of the volume will contain the results of "Heliometer Observations of the Satellites of Jupiter."

The Cape General Catalogue of 3007 stars for 1890, with appendices, has been distributed.

The day-numbers for the year 1901, corresponding to Finlay's star-reduction tables, have been distributed; those for 1902 are printed and will be soon distributed.

The annual results of meridian observations 1896–97 are in the press. The MS. of these results for 1898 is ready for press. The annual results of the meridian observations 1866–70, made under the direction of Sir Thomas Maclear and recently reduced, are in the press. The annual results of meridian observations 1877, made under the direction of Mr. Stone, are also in the press; those for 1878 and 1879 are ready for press.

The Cape General Catalogue of 1905 stars for the equinox 1865, based on the Cape meridian observations 1860 to 1870, has been completed and passed through the press, and should soon be in the hands of astronomers. This work completes the arrears of publication of the Cape meridian observations.

The list of 2798 zodiacal stars for the equinox 1900, prepared by H.M. Astronomer in accordance with Resolution 9 of the "International Conference on Fundamental Stars," held at Paris in the year 1896, has been passed through press and distributed.

The work of the present transit circle has been chiefly confined to the completion of the observations of standard stars required for the reduction of the international "Catalogue

Plates." During the year the whole of the standard stars between Declination $-48°$ and $-51°$ (both inclusive) have been observed, with a minimum of three observations for each star. We have thus now good recent meridian places of from 10 to 12 well-distributed standard stars for each of the plates of the Cape astrographic zone $-40°$ to $-52°$.

The observations made with the transit circle during the year have been :—

Meridian Transits	... ...	9450
Determinations of Z.D.	... ...	8947
" Collimation	... ...	99
" Level	... ...	331
" Azimuth	... ...	306
" Runs	... ...	317
" Nadir	... ...	318
" Flexure	... ...	21

The reductions of the meridian observations to mean place both in R.A. and N.P.D., and the formation of the Ledgers, is complete to 1899 December 31.

The General Catalogue of standard stars Declination $-40°$ to $-52°$ for the Cape astrographic plates, now in course of preparation from the Cape meridian observations 1896–99, will contain 8556 stars.

A new working list for the transit circle has been prepared, and contains :—

1. All stars of $8\frac{1}{2}$ magnitude or brighter which are catalogued in the *C.P.D.*, but which are not to be found in any catalogue of precision yet published.
2. All of the 2798 stars of the zodiacal list.
3. All stars of which occultations have been observed at the Cape, and which do not occur in the Cape General Catalogues for 1885 or 1890.
4. Stars which, from the revision of the *C.P.D.*, appear to require further meridian observations to settle questions connected with their proper motion.
5. Stars used for latitude determination in either of the two Cape geodetic surveys.
6. Comet comparison stars.

The new transit circle will be entirely devoted to systematic meridian observation of the Sun, *Mercury*, *Venus*, and fundamental stars.

Observations of 115 separate phenomena of occultations were obtained as follows :—

	D.B.	D.D.	R.B.	R.D.	Total.
Predicted by the N.A. Office ...	2	13	2	15	32
Other occultations	0	73	0	10	83
Total number of separate phenomena					115

Of these phenomena, twenty-one were observed by two observers, and six by three observers.

A list of 893 occultations observed at the Cape between 1881 and 1898 has, at the request of Monsieur C. André, been published in the *Astronomische Nachrichten*, Nos. 3599–60.

Tuttle's Comet was observed on seven nights, and Swift's Comet on one night, with the 7-inch equatorial; Tempel's Comet was observed at meridian passage on twenty nights with the transit circle. Finlay's Comet was searched for on four nights with the 18-inch telescope of the McClean equatorial, but without success. The results of these observations of comets have been communicated to the *Astronomische Nachrichten*. In addition to the lists of stars mentioned in last report in connection with the revision of the *Cape Photographic Durchmusterung*, two further lists, consisting of stars contained in catalogues of precision but missing in the plates, have been received from Professor Kapteyn. All stars in these and previous lists have now been looked for, and a summary of the results appears in the introduction to the third part of the *C.P.D.* A further list of suspected variable stars is also under observation, together with a few other stars chosen chiefly from Chandler's third catalogue. Some of the results have been published in the *Astronomical Journal*, Nos. 468 and 470. The star *C.P.D.* $-41^\circ.1681$ has been found to be an Algol variable, and the star *C.P.D.* $-49^\circ.10361$ a variable with the remarkably short period of $7^h\ 28^m$.

In course of these revisions eighteen previously unrecorded double stars have been found by Mr. Innes with the 7-inch equatorial, two by Mr. Cox with the transit circle, and one by Mr. Pead with the same instrument.

Twenty-one close double stars, previously unmeasured, have been measured with the Repsold micrometer attached to the 18-inch visual telescope of the McClean equatorial, and two new close double stars have been found by Mr. Innes with the same instrument. Many previously unrecorded faint *comites* to known double stars have been noted, but are not included in these figures.

The McClean Equatorial has been chiefly employed in connection with the slit spectroscope, as the colour-correction of the object-glass was unfavourable for use with the object-glass prism.

A great deal of time has been given to investigations on the systematic errors to which measures of velocity in the line of sight are liable.

Between January 19, when the slit spectroscope was mounted,

and October 13, when the photographic object glass was dismounted, the following photographs were secured :—

	Plates.
With the object-glass prism	15
Stellar spectra with slit spectroscope	114
Chemical spectra	106
Investigation of the colour-curves for focus of the slit spectroscope and for adjustment of collimator for rays of different colours (Newall's method) ...	111
Total ...	346

A number of these spectra have been measured, and papers have been communicated to the Royal Society on the existence of oxygen and silicon in certain classes of star spectra.

Regular observation of all oppositions of major planets with the heliometer has been continued; the following observations were secured in 1899 :—

	No. of Measures.
Opposition of *Mars*	18
" *Uranus*	49
" *Jupiter*	40
" *Neptune*	33
" *Saturn*	10

In Triangulation I. (which connects thirty-six stars available for *Uranus* in 1898, 1899, and 1900, *Saturn* in 1898, and *Jupiter* in 1900), forty-nine distances in the triangulation with twelve measures of the standards have been obtained in 1889, in addition to 141 distances and seventy position angles measured in 1897 and 1898. In Triangulation II. (connecting together nineteen stars required for heliometer observations of *Neptune* in 1897, 1898, 1899, and 1900), there have been measured in 1899 thirty distances in the triangulation and thirteen standards, in addition to eighty-three distances with thirty standards and seven position angles with four standards measured in 1898.

In the triangulation of the *Jupiter* comparison stars for 1898, thirty-six distances with seventeen measures of standards have been observed ; in the triangulation of the *Jupiter* comparison stars for 1899, fifty-five distances with nineteen standards and twelve position angles with six standards were observed. All the observations connected with the triangulation of *Jupiter* standard stars were made in 1899.

The heliometer triangulation of the South Polar area has been continued. During the course of the year 202 observations of distance in the triangulation, with sixty-five observations of the standard distance, have been secured, in addition to 311 observations of distances and 103 observations of the standard distance secured in previous years. The heliometer observations for this

triangulation are now nearly complete. In connection with the same object, nine astrographic plates, covering the same area, have been secured. The combination of the heliometer and photographic measures with all existing data from meridian observations will be employed to derive definitive places of the stars within 2° of the South Pole for the equinox 1900.

Forty sets of heliometer observations for stellar parallax, and 14½ sets of observations of red stars relative to normally coloured comparison stars at large hour angles E. and W. of the meridian, have been observed.

Heliometer observations of the conjunction of *Mars* with *Regulus* were made on two nights.

As stars used to determine the screw value of the Repsold micrometer when attached to the McClean equatorial, the distance and position angle of ζ_1 and ζ_2 *Reticuli* were observed with the heliometer on three nights, and of β and γ *Horologii* on two nights.

Comet Swift was observed with the heliometer on eight nights, its position being referred to twenty-seven different stars.

Nearly all the heliometer observations have been reduced to arc, corrected for aberration, refraction, &c., and are ready for final discussion.

Mr. de Sitter has completed the series of observations with Zöllner's photometer which he carried out for the purpose of determining the relation between the visual and photographic magnitudes of stars in different galactic latitudes.

The systematic reduction of the series of 550 heliometer observations of the mutual distances and position angles of *Jupiter's* satellites, and the comparison of the observed with the corresponding tabular quantities, is now completed. The coefficients of such elements of the system and such periodic terms as can be determined from the observations have been computed, and the normal equations are formed. The solution of the normals is not yet completed, but it is already evident that the results will furnish considerable and accurately determined corrections, especially to the nodes and inclinations of the orbits of the satellites.

With the astrographic telescope the following work has been accomplished :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Triple image Chart Plates, passed	152	456	30^m
„ „ „ „ rejected	40	120	30^m
Revision Catalogue Plates ...	184	552	$6^m, 3^m, 20^s$
Iris Plates...	78	468	3^m to 1^m
Galactic Comparison Plates ...	6	12	10^m
Polar Plates	9	27	$6^m, 3^m, 20^s$
Various (foci, adjustments, &c.)...	12		
	481		

With reference to the revision catalogue plates, it is intended, as mentioned in last report, to repeat the whole series, in order to bring the epoch at which the plates were taken nearer to that at which the comparison stars were observed on the meridian.

The 78 plates of *Iris* were taken during the period July 11 to the end of the year, and the series will be continued until the middle of January 1900. There are 6 exposures on each plate. It is intended to utilise the results of measurement of these plates, in combination with meridian observations of a number of comparison stars, to determine the mass of the Moon.

The new measuring machine, devised by H.M. Astronomer, which is mentioned in last report, has been in constant use throughout the year, although a great deal of time has been lost in training observers The second measuring machine of the same type was received from Messrs. Repsold only in the beginning of November; but its micrometer had to be returned for some small alterations, so that only one machine has been available throughout the year for all purposes.

During the year 103 plates containing 38,758 stars have been measured in both coordinates in each of two reversed positions of the plate, and all the standard stars on each plate have been similarly measured by both the observers. When a coordinate of any star, as measured in one position of the plate, differs by $0''\cdot6$ from the corresponding coordinate resulting from the measure in the reversed position of the plate, the observations in both positions have been repeated. The total number of plates now definitely measured is 126. The conversion of the measures into rectangular coordinates has been completed for 102 plates, and for 87 of these the work is completely examined and the final copy prepared for press.

With cameras attached to three equatorials, attempts were made to photograph the paths of the *Leonid* meteors on November 14, 15, and 16. Plates were exposed from the time of rising of the radiant until dawn, but without success.

The numbers of meteors observed by eye were:—

Nov.	Separate Leonids.	Hourly No.
14	15	12·0
15	6	3·8
16	4	2·3

The seismograph was brought into use on August 1, and the records have been forwarded monthly to Professor Milne since that date.

The geodetic survey of Rhodesia has been steadily pushed forward. H.M. Astronomer visited Rhodesia in May, reorganised the observing party, and started the arc of meridian from Gwelo northwards approximately along the 30th meridian of E. longitude. From January to May 15 ten stations were occupied, extending eastward to Bungwe (lat. 19° 51′ S., long. 30° 19′ E.). Between

May 15 and July 20 fourteen stations were occupied with the theodolite, and the angles of the triangles in the arc were measured as far as lat. 18° 35′ S. The reconnaissance and beaconing of fourteen stations carried the arc to N'yamanje (lat. 16° 30′ S., long. 30° 45′). Here the smoke from grass fires compelled stoppage of the work for the season, and the party returned, *via* Salisbury, to Gwelo, where latitude and azimuth were determined. The intended telegraphic determination of the longitude of Gwelo was prevented by the outbreak of the Transvaal war, and interruption of telegraphic communication by the Boers. The astronomical point at Gwelo was connected with the main triangulation, and the observing party was disbanded for the season. During the year astronomical latitude was determined at five stations, and astronomical azimuth at two stations. Complete reorganisation will be required for northern extension of the work, and transport by native carriers must be substituted for the wagon transport hitherto employed. Mr. Alexr. Simms, who has been in charge of the field work throughout, returned to the Observatory in the end of December *via* Beira and Delagoa Bay, where he will be occupied in connection with the reduction of the observations, and in preparation for renewal of field work in March, when the season is again suitable. The operations of the Anglo-German Boundary Survey are in steady progress, but have been rendered very tedious and indirect by the flat and arid character of the country.

The report of the survey of a part of the Cape Colony and British Kaffraria made by Captain Bailey, R.E., in 1859–62, was printed and presented to the Cape Parliament in 1863. The work contains many errors and inconsistencies, and, in its present state, is quite unfit to form a basis for further accurate survey. Accordingly, all available original data have been collected, and the whole work has been recomputed and reduced to consistency with the results of the geodetic survey. The new work is in the press. The meteorological observations made during 1899 have been communicated to the Cape Meteorological Commission.

No change has occurred in the staff except that Mr. W. de Sitter, a former pupil of Professor J. C. Kapteyn, who has served as a computer at the Cape Observatory since August 1897, returned in December to Holland to take up the post of assistant at the Astronomical Laboratory, Groningen. At the Cape Mr. de Sitter availed himself of the opportunity to study practical astronomy, and has carried out several researches of considerable importance during his stay.

Two computers, and also the optical fitter and the carpenter, who were all members of the Cape Volunteer Artillery, have been called out for active service at the seat of war; the work of the Observatory has necessarily suffered by their absence.

Royal Observatory, Edinburgh.

The Observatory buildings and grounds have been maintained in excellent order by H.M. Office of Works. The instrumental equipment has been increased by the acquisition of a Cooke triple object-glass of 6-inch aperture. This has been mounted on the equatorial stand in the "6-inch" house. Its performance for observation of double stars when the magnitudes are very unequal, and for occultations, has been found extremely satisfactory, the achromatism and correction for figure being practically perfect.

A vacancy was caused in the personal staff of the Observatory by the lamented death of Mr. Andrew James Ramsay on March 5. Born at Crieff 1862 March 27, he had thus not quite completed the 37th year of his age. His loss is keenly felt by his colleagues, with whom he had been associated for a number of years, both during his University career and more particularly since his appointment as Assistant Astronomer in 1893. A short account of his astronomical work will be found in vol. ix., No. 6, of the *Journal of the British Astronomical Association.* The vacancy was filled in April by the appointment of Mr. George Clark, M.A., to the position of Second Assistant Astronomer.

The time service for the cities of Edinburgh and Dundee has been carried on as in past years. In addition to the clocks used for automatically firing the gun and dropping the time-ball, four other clocks are directly controlled by the Molyneux Mean Time Clock of this Observatory, besides a number of others controlled by secondary circuits. The signal by time-ball was unfortunately interrupted from September 30 to October 10, for repair of part of the machinery, and again on November 3, when it was considered inadvisable to raise the ball on account of the violence of the wind. The gun was accidentally fired incorrectly on April 4, through a derangement of the clock at the gun, and was under repair on May 25. With these exceptions, the time service has been satisfactorily carried out. Time observations were made on over a hundred nights with the meridian circle, and from these the rate of the Brisbane sidereal clock was determined. This clock, which is enclosed within an airtight case, continues to give satisfaction, its rate having altered but slightly during the year. In September the pendulum of the Frodsham sidereal clock was suspended from a new cast-iron back, to which the contact-springs of the chronograph circuit are also attached. Formerly the springs were fixed to the wooden back of the clock-case, and the unequal expansion of the wood and the steel pendulum-rod prejudicially affected the clock rate, as well as the working of the chronograph. The improvement thus effected in the going of the clock and the action of the contact-springs at once became apparent.

The meridian observations have been carried out during the year by Dr. Halm, assisted since July by Mr. Clark. The programme of observations has been the same as that of last year, comprising the list of *Nautical Almanac* zodiacal stars and the stars employed by Dr. Gill in his heliometric measurements of the positions of the outer planets. In addition to these, regular observations of the Pole Star in both coordinates and of the standard stars used for determining the correction of the clock were made on all possible occasions. The total number of observations made is 2000, for all of which the chronograph signals have been duly recorded and the means of the microscopes deduced. The instrumental errors were ascertained at frequent intervals, and were found to remain remarkably constant; the difference, for example, between the maximum and minimum values of the azimuth amounting to no more than 2″.

As regards the new reduction of the observations made under the direction of the late Professor Henderson, the right ascensions from 1834 to 1845 are now finished, the only part of the work still to be done being the reduction of the mean places to the equinox 1840·0. Considerable progress has also been made in the reduction of the declinations, the years 1841 to 1845 having been completed, while comparatively little now remains to be done to the preceding years. It is therefore confidently expected that the final results will be published in the course of the present year. The application of the clock corrections, and those for the position of the instrument in right ascension were carried out for the most part by Mr. Clark, while Dr. Halm chiefly devoted himself to the reduction of the declinations. This latter part of the work was greatly facilitated by the admirable investigation, of Professor Boss, into the division errors of the mural circle employed by Henderson. In the course of the computations much assistance was rendered by Mr. Neustadt, who has acted as temporary computer.

Some damage was caused to the East Dome by a violent storm on the night of November 10, a part of the outer copper covering of the roof being torn away. The repairs were executed by H.M. Office of Works before the end of the month, the torn copper, which weighed 16 oz. to the square foot, being replaced by stronger material weighing 22 oz. to the square foot.

The 15-inch refractor was used during the year by Mr. Heath for micrometric observations of the minor planets. A few occultations were also observed, and in June eight determinations of the place of Swift's Comet were obtained by Mr. Heath and Dr. Halm. A number of observations of close binary stars were also made by Dr. Copeland.

The occultations of small stars predicted to take place during the nearly total Lunar Eclipse of December 16 were observed with three telescopes. In all, thirty-three observations of stars were secured, thirteen by Dr. Halm with the 6-inch, nine by Mr. Heath with the 15-inch, and eleven by Mr. Clark with the

12-inch reflector. *Neptune* was occulted soon after the eclipse, but nothing was seen of it by any of the observers here.

The meteorological observations have been made by the staff on the same lines as in former years. The bi-daily readings of the barometer, wet and dry bulb thermometers, wind and cloud, and daily readings of the shaded and exposed maximum and minimum thermometers, have been continuous throughout the year. The Robinson Anemometer and King's Barograph have also been in operation without interruption. A monthly copy of the daily readings has, as usual, been supplied to the Secretary of the Scottish Meteorological Society for the use of the Registrar-General for Scotland, and the monthly means have been published in the Registrar's quarterly returns. The weekly readings of the Rock thermometers at Calton Hill have been continued. The observations since 1879 are now being prepared for publication by Mr. Heath, along with a summary of the whole series from the commencement in 1837 to the end of 1899.

The two bifilar pendulums and photographic recording apparatus have been kept in action all the year. Though the record is fairly continuous, no disturbance of an interesting character has been found on the photographs. During the summer considerable difficulty was experienced from the stopping of the clock and the gradual discoloration of the paraffin oil in which the pendulum mirrors are suspended. Eventually, rectified spirit of turpentine was substituted for the paraffin oil. So far, this has proved more transparent to photographic rays than the paraffin oil, with a corresponding improvement in the distinctness of the curves.

Watch was kept for the expected shower of *Leonid* meteors on the nights of November 14 and 15. The night of the 14th was cloudless; but on the 15th the sky was partly obscured by haze, and at 14^h a thick fog came on. On both nights the presence of a nearly full Moon made observations of the fainter meteors difficult or impossible. The paths of 74 *Leonids* were laid down on previously prepared maps by Dr. Halm and Mr. Clark. From these two determinations of the radiant-point were computed, by Mr. Clark, and the result laid before the Society in a paper which appeared in vol. lx., No. 2, of the *Monthly Notices*. An attempt was made by Mr. Heath to photograph the radiant-point with two cameras, one of which carries plates, 18 × 16 inches, attached to the tube of the 24-inch reflector, but without success. A few *Bielids* were unexpectedly seen on the evening of Saturday, November 25.

Armagh Observatory.

On January 31 a micrometer for measuring photographic plates was received from Messrs. Troughton & Simms, paid for by a grant made by the Government Grant Committee. It is a modification of the Greenwich instrument figured in *Monthly Notices*, vol. liii. p. 327, and can be used either for measuring rectangular

coordinates, one at a time, or polar coordinates. The settings on the objects are made with a microscope with a simple cross-wire, while the glass scale is read by a micrometer carrying parallel wires. The plate holder is furnished with a position circle, and is counterbalanced by a weight attached to it by a chain passing over a pulley, the whole instrument being inclined at 45° to the horizontal plane.

Owing to the delay caused by various minor alterations which had to be made in the instrument, as well as by other circumstances, regular work with the instrument has only recently been commenced. Several plates of the *Pleiades*, lent by Dr. Roberts, have been measured for the determination of scale value, distortion, &c., and a number of plates of nebulæ are shortly expected, which Dr. Roberts has kindly undertaken to furnish for the purpose of their being measured and discussed at Armagh.

During the nights when the *Leonids* were expected it was totally cloudy here, except from 1.30 to 2.0 on the morning of the 16th, when three observers only saw two meteors, one of which was not a *Leonid*.

Cambridge Observatory.

Meridian Circle.—The meridian circle was used for observation on 122 nights in the course of the year 1899, and frequent observations were taken by day of standard stars, especially *Polaris*.

The re-observation of the faint stars, of which the places in the catalogue of the *Astronomische Gesellschaft* depend each on a single observation, which was begun in 1897 March, is now completed. To this end 805 complete observations of these stars were made during the year. The reduction of these observations is approaching completion, and in a short time the results will be ready for examination and comparison with the single places given in the Catalogue.

In 1899 March the work of observing Dr. Gill's list of heliometer comparison stars was begun. Six hundred and eighty-four observations of 92 stars have been made, and the places are obtained and reduced to the mean equinox at the beginning of the year.

The list of Harrow occultation stars, furnished by Col. Tupman, is approaching completion, 331 observations having been made during the year; so that at present there remain only 16 of these stars unobserved. The reductions of all these observations are well-nigh complete.

An observing catalogue of stars near the ecliptic is in course of preparation, and the work of observation and reduction is actually begun. Three hundred and thirty-two observations of these stars have already been made in the latter part of the year.

As an essential part of the work there have also been made 762 observations of standard stars for clock error, and 87

observations of *Polaris* at the upper transit, and 103 at the lower, for instrumental deviation. The observations of *Polaris* have also been used in making a fresh determination of the intervals of the wires, although these have remained intact during the year.

The nadir point, level, and line of collimation have been carefully and regularly observed, and the constants for instrumental correction have been obtained from 160 equations.

After each observation for level and line of collimation the transit wires have been always adjusted so as to leave the observations practically free from error of collimation, and from the effect of diurnal aberration.

Sheepshanks Photographic Equatorial.—The work for the year has consisted almost entirely of experiment and alteration. In 1899 February the flexure of the objective tube was determined. It was found to be large and unsymmetrical with respect to the meridian, and Sir Howard Grubb undertook to make a new and much stronger tube. Trial photographs showed very poor definition, due to air currents in the tube. The instrument had been sent to Cambridge without any provision being made to close in the elbow joint and protect the mirror. March was spent in designing and making an experimental covering for the elbow joint, both above and below, by which the free circulation of air in the path of the rays was almost entirely prevented. So much improvement in the definition resulted that it was decided to carry out the plan in permanent form. The necessary additions to the instrument, in accordance with specifications and plans prepared at the Observatory, were ordered from Sir Howard Grubb. In June the old objective tube was returned to him, and the work put in hand. It was completed and the instrument partly readjusted by Christmas. In 1900 January the plane mirror was resilvered at the Observatory, and the instrument is now, at the end of January, practically in working order again.

The measuring machine which is being made by the Cambridge Scientific Instrument Company is approaching completion.

Northumberland Equatorial.—With a 5-inch portrait lens attached to the instrument a number of photographs for measurement were made of comet Swift 1899.

Extensive preparations were made to observe the *Leonids*, and we shared the general disappointment. Twenty-one plates of the region about the radiant point were secured with the portrait lens, and a preliminary examination shows only one trail. Visual observations gave 150 meteors distributed over twelve hours of clear or partially clear weather on the nights of November 13, 14, 15; and a number of trails were plotted. Twelve members of the University assisted in this work.

Observations of the partial eclipse of the Moon, 1899 December 16, were stopped by clouds shortly after first contact with the shadow.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observations on 110 nights in the course of the year 1899, as compared with eighty-five nights in 1898 and with eighty-two nights in 1897. The atmospheric conditions have for spectrographic purposes been much better than in the three preceding years.

In the first half of the year the instrument was used in connection with the Bruce spectroscope in taking photographs of stellar spectra for the determination of velocity in the line of sight. Before July 24, eighty-eight photographs suitable for measurement had been obtained, giving material for the determination of velocity for thirty-one stars.

The Bruce spectroscope was dismounted 1899 July 24, it having been decided for various reasons that the set of observations for which the instrument was designed should be brought to a conclusion. The present seems to be a fitting opportunity for giving a brief summary of the work done with the instrument. The Bruce spectroscope (single prism) was ready for work in the late autumn of 1895; and in the course of the next twelve months more than 200 photographs of stellar spectra had been obtained. The discussion of the results of the measurements showed, however, that there were more or less systematic differences between the velocities determined at Cambridge and those at Potsdam and elsewhere. This led to the discovery of a defect in the instrument, in consequence of which a minute deflection of the collimator had been produced every time the reflecting prisms for photographing the comparison spectra were used. It was accordingly found necessary to reject nearly 150 photographs of stellar spectra as valueless for the determination of the velocity in the line of sight. The defect in the instrument was remedied in 1897 February, and since that date 340 photographs of stellar spectra have been obtained, affording material for determination of velocity for eighty-five stars in all. Of these, thirty-five stars are included in the Potsdam list of fifty-one stars. Thus fifty additional stars of magnitude between 2·0 and 4·5 will be dealt with; it is, however, anticipated that it will not be possible to deduce trustworthy velocities for all of these, because certain of the spectra have indistinct lines, such as are seen in the spectra of α *Aquilæ* and β and δ *Leonis*. In addition to many other stellar photographs taken, but rejected as faulty or insufficiently exposed, 461 photographs have been taken with the instrument in the laboratory and in the observatory, either for testing the adjustments of the spectroscope or in connection with investigations of special points arising in the course of the study of the stellar spectra.

The measurement and reduction of the photographs, and the discussion of results, have proved more troublesome than was anticipated, chiefly on account of the fact that different methods

had to be found for spectra of type other than solar. Reference was made in last year's report to the development of another method of reduction. This method is applicable to spectra of all types, and has been in use for the last fourteen months. It is nothing more than the most direct determination of wave-lengths of the stellar lines in terms of the comparison spectrum of the iron spark. The wave-lengths thus determined are affected by velocity, which can at once be deduced when the lines have been identified with the lines of known elements, and consequently of known wave-length. The relation used for the interpolation of wave-lengths is the old relation first used by Cornu, by the revival of which Hartmann of the Potsdam Observatory has done such good service—viz. $\lambda - \lambda_0 = c/(R_0 - R)$. In April a Brunsviga calculating machine was pressed into the service, and proves even more satisfactory than was anticipated.

The measurement of the photographs of this series is temporarily interrupted pending the arrival of a new micrometer, with which it will be possible to measure a much longer range of the spectrum, and consequently to obtain a greater choice of suitable lines than heretofore. Meanwhile, the old micrometer is being used in other measurements.

Within five days of its being dismounted, the Bruce spectroscope (single prism) was converted into a four-prism spectroscope, preparation having been made beforehand to attach the strong cast-iron prism-box with four prisms, which had been made for use in the Indian eclipse of 1898.

During the last five months of the year sixty-six photographs have been obtained of the spectra of bright stars with this powerful instrument. The scale of the spectra is approximately 1·5 tenth-metre per revolution of the micrometer, or about 6 tenth-metre per millimetre. These are obtained with a camera whose effective focal length is about 1,000 mm., and whose aperture is *f*/20; and in spite of the fourteen inches of glass in the total base of the prisms, sufficient light gets through the prisms in about an hour's exposure to give spectra of the brightest stars of density enough for accurate measurement. (With a camera of focal length about 500 mm. and aperture *f*/10, the spectra obtained show admirable definition, and when the present investigation is completed the instrument will be used with the shorter camera for fainter stars.) Spectra of twelve out of fifteen stars on the working list have been taken, and one of the first results obtained with the instrument is the discovery of the binary character of *α Aurigæ*, which was lately announced (*ante*, p. 2). Twenty-three photographs of the spectrum of this star have been secured, and the preliminary measurements with a micrometer of small range seem to show that the period of the new binary is 104 days.

Dunsink Observatory.

Up to September systematic observations have been made with the meridian circle in order to determine the positions of stars of reference for star clusters, and, at Dr. Gill's request, the positions of stars of reference for the major planets. The number of observations is 2399, including 79 of collimation error, 81 of level, 15 of the error of runs of the microscopes, and 69 of the nadir point. Sixty-three transits of polar stars were also observed for determining the azimuth, 304 transits of standard stars for the error of the Dent sidereal clock, and 284 zenith distances of standard stars for the equator point. The observations of stars on the working list amount to 1046 in R.A. and the same number in Declination.

The interval from September to the close of the year has been occupied in preparing these observations for press. This work will be published as Part IX. of the *Astronomical Observations and Researches made at Dunsink*. It will contain the results of observations of 321 stars, from an average of four observations for each star. As already stated, the stars are reference stars for clusters, together with some other stars observed at Dr. Gill's request.

The Roberts' Equatorial has been used chiefly in photographing clusters of stars. The number of plates taken during 1899 is 116.

Observation of the partial solar eclipse in June and of the lunar eclipse in December was impossible, the sky being quite overclouded on both occasions. A watch was kept continuously for three nights and for part of a fourth in the hopes of seeing or photographing the *Leonids*. Only two or three meteors were seen, owing to the unfavourable weather.

As usual the time service to Dublin has been kept up, a time-ball being let fall daily at 1^h G.M.T. The usual facilities have been allowed to visitors.

Durham Observatory.

We have to record the decease of Mr. H. J. Carpenter, who had filled the post of Observer for fourteen years. He resigned the post shortly before his death.

Mr. F. C. H. Carpenter, formerly of the University Observatory, Oxford, has been appointed Observer.

During the year the house for the Almucantar has been built, on a spot a little to the S.E. of the old buildings; Messrs. T. Cooke & Sons have completed and delivered the instrument, and it will be erected in the course of a few days. Tables have been computed to facilitate reduction of its observations.

Professor E. C. Pickering having kindly communicated to the

Director his photometric observations of *Jupiter's* fourth satellite, an extensive piece of work has been begun in discussing these. Provisional corrections to Damoiseau's Tables of IV. have been deduced, showing large and well-marked errors, amounting to several minutes of time.

Watch was kept for the *Leonids*, and an attempt was made to enlist the co-operation of observers in scattered positions over Yorkshire, Durham, and Northumberland. The result is published in *M.N.*, 1899 December.

Meteorological observations have been continued as usual.

Glasgow Observatory.

The transit circle was used during the year for the observations of the star *BD* 89° 37, and of α and λ *Ursæ Minoris*, in continuation of the work which was begun three years ago. The rectangular coordinates of *BD* 89° 37, which has at present a polar distance of 7′, are measured in a bright field by means of the two micrometers of the instrument at intervals of about three hours. Each night's observations determine the coordinates with reference to the pole, and the adjustment with reference to the vernal point alone requires the knowledge of approximate sidereal time. The errors of the instrument are derived from the same observations, allowance being made for their changes during a night as found from settings on the collimators, nadir and azimuth mark. The coordinates are therefore fundamental and well suited for the determination of the constant of aberration, and the motion of the pole, independent of the change of latitude. Unfortunately the weather again proved adverse to the work. Although time observations were possible on 142 nights, there were only thirty-eight nights during the year, April excepted, on which observations of faint objects could be carried on. Twenty-six nights were devoted to the transit circle, but only on sixteen nights could two or more observations of *BD* 89° 37 be obtained. The instrument was reversed in its bearings twelve times. The distortion of the field was derived from transits of λ *Ursæ Minoris* over the whole field, the error being about 0″·3 at a distance of 8′ from the centre. In recent years the division errors of the circle had been determined for each degree line. This investigation was extended to each 2′ line, which may come, for pole stars, under one of the eight microscopes in the two positions of the circle. Twenty-four degrees were measured. The reductions brought out the fact, which perhaps belongs to all circles made by Ertel, that the division errors repeat for each of the degrees. If one assumes that after the degree lines were marked, the minute lines were filled in by being copied from the same standard scale, the average error of copying works out to 0″·30, while some of the individual division errors amount to four times that quantity; for

instance, the average difference of the corrections of the 18′ and 16′ lines is $+1''\cdot18$, and of the 20′ and 18′ lines $-1''\cdot17$, and the twenty-four determinations made all over the circle differ from these only by $0''\cdot3$ on an average; and so it follows that the position of the 18′ line of the standard scale was 1″ out. It is apparent that these errors systematically affect the declination of a star during a number of years, if only the errors of the degree lines were taken into account.

The "Breadalbane" reflector, with its spectroscope, was principally employed on the *Orion* and *Andromeda* nebulæ. The observations with this instrument had to be interrupted during the summer months of the year, on account of the definition of the large prism being impaired by the great changes of temperature in the dome after a sunny day. In October a plate was exposed on the spectrum of the *Andromeda* nebula, and re-inserted into the camera on every clear night. For this purpose the plate-holder carries an eyepiece with cross wires, and is capable of adjustment in the camera by means of two delicate screws. The fiducial point is given by a line of the spectrum of magnesium. Until the end of the year there were only five clear nights, which yielded a total of twenty-two hours. As it is not expected that less than 100 hours will suffice, the plate will probably be lost. A fresh attempt will be made next autumn.

A look-out was kept for the *Leonids* on November 14 and 15 until daybreak. On the first date it was clear after midnight, and twenty-one meteors were counted at regular, but not uninterrupted, watches. A distinct increase in the numbers occurred between 5 and 6 A.M. On the second date only a few were seen on a hazy sky, which became overcast soon after midnight.

The time service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The character of the work pursued at the Liverpool Observatory has not altered from that of previous years. The Dock Board keep steadily in sight the desirability of making the Observatory useful to the requirements of the Port, and consequently the distribution of time signals, and the examination of nautical instruments deposited for the purposes of examination and correction, form a large part of the routine work of the Institution.

The transit instrument and equatorial are maintained in efficient repair and constant use. An examination of the behaviour of the level and azimuth errors of the former, to which reference was made in the last annual report published by the Board, has been extended so as to embrace several years, and the existence of an annual period of considerable amount is still further disclosed. Some attempts have been made to detect a diurnal period, but various circumstances have combined to defeat a rigorous inquiry of this character. The observation

of certain circumpolar stars suggested by Professor Auwers is, however, still continued in the hope that they may eventually be useful for this purpose.

The Equatorial is used for the observations of comets, of occultations, and for the measurement of the diameter of planets. The low altitude of *Jupiter* and *Saturn* has, however, much interfered with the prosecution of this last inquiry, and some of the anomalies which have been detected while employing various micrometers and with different illuminations still remain unexplained. With the view of still further examining the micrometers and eliminating the question of artificial illumination, a series of measurements has been commenced on *Venus*.

Arrangements were made for observing and photographing the anticipated *Leonid* shower; these were defeated by the weather and the paucity of the meteors.

The seismological observations are still continued. By the kindness of the Earthquake Committee of the British Association, a second bifilar seismograph has been added to the equipment, which will be placed to register disturbances in a plane at right angles to that previously used. Some necessary alterations and additions are still being made to this instrument, but it is hoped shortly to continue the inquiry, which has been interrupted pending the erection of the second instrument.

The meteorological observations, of which the results are forwarded to various local authorities, are carefully maintained. Hitherto it has only been possible to secure hourly records of pressure, wind, and rain, no provision being made for the automatic registration of changes of temperature. This defect is now being removed by the erection of a self-recording hygrometer, funds having been voted by the Marine Committee for that purpose. The Dines Anemometer appears to work satisfactorily, but the disagreement between its records and those of the well-known Osler type is as marked as in previous years.

Radcliffe Observatory, Oxford.

The observations with the transit circle during the first three months of the year were carried on with vigour; and during this period, owing to the unusual succession of cloudless nights, the number of transits observed amounted to 1269, and the North Polar distances for the same period to 1057. On March 29 Mr. Rudolf Grubb arrived to set up the new chronograph, and from April 1 it became necessary to discontinue regular observations owing to experiments with the standard clock. The movement of this clock was, on May 3, sent to Messrs. E. Dent for a new attachment of contact springs for registration of the seconds upon the barrel of the chronograph. This work and various experiments for the adjustment of the registering apparatus

lasted intermittently till June 7. Good progress was made from June till September with stars in the working list.

In October it was decided to undertake the reduction of Dr. Hornsby's observations made at this Observatory in the year 1774 with Bird's transit instrument and quadrants, and for this purpose all observations were stopped, so as to put the whole strength of the staff into the work. The observations of that year (1774) have been reduced as a specimen, to enable a judgment to be formed of the value of the enormous mass of unpublished observations made at this Observatory by Dr. Hornsby and his successors, with the same instruments, between the years 1774 and 1838. The results have been communicated to the Society (*ante*, p. 265), and are of a very striking character. The mean error of an observation in R.A. is only $\pm 0^s{\cdot}08$, as compared with $\pm 0^s{\cdot}21$ found by Bessel for Bradley's observations.

Notwithstanding these interruptions, the total number of observations made with the transit circle amounted during the year to 2664 in R.A. (including 91 of the Sun and 24 of the Moon), whilst the N.P.D.'s amount to 1957 (including 88 of the Sun and 25 of the Moon). The nadir and level were observed 119 times.

As parts of the working catalogue had been worked out, the whole has been revised and many additions made. It now contains all stars down to the 7·3 magnitude between $+5°$ and $0°$ decl.; some stars with large proper motions, and, in areas where brighter stars did not exist, some of fainter magnitude than 7·3 have been inserted.

All the Zodiacal stars in the working catalogue, which had been inserted from Dr. Downing's list, have now been observed; but the reductions are in a backward state, owing to the many other branches of work which have engaged our attention.

With the Barclay equatorial several observations of comets, nebulæ, and variable stars have been made, the results of which, in some cases, have been already communicated to the Society.

The observations of the *Leonids* on November 14, and the result of the watches on November 15, have been communicated to the Society.

The printing of the results of the Radcliffe observations made in the years 1890–91 has been completed, and the volume was distributed during the summer.

The meteorological observations and automatic registrations have been maintained as usual during the year.

The underground platinum resistance thermometers have worked very satisfactorily. Readings of the five thermometers buried in the soil at depths of 6 in., 1 ft. 6 in., 3 ft. 6 in., 5 ft. 10 in., and 10 ft. respectively, and of a similar one "A" suspended in air in the observing room, have been taken every day and reduced to the air scale. In October thermometer "A" and the upper one of the buried instruments were carefully re-standardised; and as the fundamental points were found to have remained

practically stationary during the year elapsed since their previous standardisation (the greatest difference being $0^{\circ}\cdot 03$ C.), it was not thought advisable to go to the labour of exhuming the deeper ones for the present.

The erection of the chronograph has already been referred to. This instrument is of Sir Howard Grubb's latest pattern. It consists of two barrels nine inches in diameter (so that a second space is very nearly half an inch long), with a driving clock electrically controlled by the sidereal standard. Each barrel runs for 4^{h} 50^{m}. The contact in the clock is made by a special wheel of sixty teeth (with one removed) attached to the escapement arbor. This instrument is found to work very satisfactorily.

Several alterations and improvements have been made to the transit circle. A new clamp and slow motion apparatus has been fixed to the cone of the eastern axis of the telescope, by which arrangement the clamp acts directly on the axis. The clamp is firm, and the slow motion is smooth and convenient.

On November 20 the new eyepiece and breech end for the transit circle, which had been in course of construction by Mr. Simms during the last twelve months, were brought to Oxford, and, during the next week, were fitted to the instrument. The breech end contains several improvements on the old pattern. The eyepiece is moved by screws in both directions; there is an adjustment by means of opposing screws both in focus and position angle; and the readings of the micrometer in N.P.D. are embossed on a paper strip by simple pressure of a screw, and can be read off at leisure and kept for reference. The bright wire illumination is effected by Abbé's method.

The effects of these alterations are being tested. It is also proposed to examine the form of the pivots at an early date, and a special apparatus for this purpose is now almost complete.

Early in the year the Radcliffe Trustees decided to set up a large equatorial refracting telescope, with an object glass of 24 in. aperture and 22 ft. 6 in. focal length for photographic work, and an object-glass corrected for visual rays of the same focal length and 18 inches aperture, to be used as a guider to the former. The mounting is to be of Sir H. Grubb's standard pattern, but modified so as to give complete circumpolar motion up to the zenith. The driving clock will be of the same pattern and size as that of the 26-inch at the Royal Observatory, Greenwich. The 18-inch telescope is to be fitted with two breech-pieces—one furnished with the ordinary slides at right angles to each other, to be used when the instrument is acting as a guider to the 24-inch, and the other furnished with a position micrometer for independent visual work.

The instrument is to be placed in a new tower, at present in process of erection, of thirty-one feet internal diameter. The dome is to be of steel and papier-maché of thirty-two feet diameter, with Grubb's new pattern live ring, and Gill shutter ten

feet wide at the base, and will be furnished with a lifting floor, raised by hydraulic pressure.

The discs for the two telescopes have been received some months ago from M. Mantois; and Sir Howard Grubb reports, as the results of his first trials, that they appear to be exceptionally good.

The construction of the mechanical parts is in a forward condition.

University Observatory, Oxford.

The present main work of the Observatory is the measurement and reduction of 1180 plates in zones $+25°$ to $+31°$, according to the scheme of the International Astrographic Conference of 1887. To this work it was decided to devote five years, and application was made to the Government Grant Committee for 750*l.* in five instalments of 150*l.*, of which four instalments have been received. About three and a half years' work of the five has been done, and 506*l.* paid to the computers temporarily engaged. This amount expended is 0·674 of the total estimate, and should accordingly represent 795 plates completed. Actually, 645 are completely measured and reduced, forty-nine are measured and partly reduced, and there is other work in hand in the shape of preliminary reductions. We are thus a little, though not much, behind on the estimate, which was necessarily a rough one. Two or three computers have been employed at the Observatory during the year, and Mr. T. J. Moore has continued measuring at his home near Doncaster with an instrument lent him by the Observatory.

Altogether 103,000 measures have been made during the year, 50,000 of them by Mr. Moore. Since each plate is measured twice this means 51,500 star positions, or about 20,000 separate stars. The number of plates measured was 211, giving an average of 244 stars per plate, which shows that the steps taken to reduce the work within reasonable limits have been successful; see reports for previous years.

During the year 179 plates were completely reduced. At the end of the year zones $+25°$, $+26°$, and $+27°$ were so far completed that only 11, 24, 32 plates respectively, out of totals of 180 each, yet remain to be finished.

The ledgers of Oxford places for the stars observed on the meridian at Cambridge have been kept up, and have recently afforded material for a discussion of "Magnitude Equation," or change in personal equation with stellar-magnitude (see *Monthly Notices*, lx. p. 3). It is made clear that this change is real and sensible, and can be readily measured in this way. Six other papers have also been communicated to the Society by the Professor or by Mr. Bellamy on topics connected with this work, and arising out of it. A discussion of possible optical distortion

on plates of much larger (celestial) area, taken with a doublet at Harvard, seems to show that such distortion is very small; and the question arises whether it is advisable to take "Chart" or long exposure plates on so small a scale as $2° \times 2°$, when the labour and time of taking them can be so enormously diminished by using instruments which will cover larger fields. This investigation is still proceeding.

One of the micrometers has been lent at times during the year to Mr. S. A. Saunder, for the measurement of lunar photographs kindly supplied by M. Loewy.

Mr. A. J. Walker, M.A., of New College, determined the geodetic position of the University Observatory with reference to the Radcliffe Observatory in May last (*Monthly Notices*, lix. p. 557).

Mr. F. C. H. Carpenter, who was appointed second assistant at this Observatory at the beginning of the year, left to become assistant at the Durham Observatory on September 30. Mr. H. F. Mullis has recently been appointed second assistant.

The usual lectures on Mathematical Astronomy were delivered during the year, and attended by about a dozen students.

Temple Observatory, Rugby.

The educational work of this Observatory has been continued as usual, and the interest taken by boys has been greater than in former years. The measurement of double stars has formed the work at the Observatory during hours not devoted to teaching. After a year's absence, owing to ill-health, Mr. Atkinson has returned to the Observatory.

Stonyhurst College Observatory.

The solar surface drawings in 1899 number 183, on as many days. Of these, 128 sheets are drawings of spots and faculæ, and the remaining 55 show only small spots as dots, and some faculæ. The mean daily disc-area deduced from the whole number of drawings is 0·7 units,* against 2·5 of the preceding year; and, dividing the year into two parts, January 1—July 16, and July 17—December 31, the mean areas are 1·1 and 0·2 respectively; which seem to indicate a close approach to the minimum period at the end of the year 1899.

Comparing the magnetic disturbances with the solar spot area, it may be remarked that of the seven days in the year noted for greater magnetic disturbances, four occurred in the two periods of greatest spot areas of the year, in the middle of March and at the end of June, and the remaining three occurred in the very quiet periods of solar activity in January, February, and May.

The grating spectrographs of the HK region of the solar

* $\frac{1}{5000}$th of the disc area.

spectrum number 162 on eighty-one days. On sixty-seven of these days the photographs are strong enough to show the intensities of the reversals. There is no marked difference between the results of this and the preceding year; but both collections are waiting for comparison with similar plates of a future period of greater solar activity.

Considerable preparations were made for the possible *Leonid* meteor shower. Five cameras were mounted for the meteor streaks; and one was attached to the eye-end of the Perry Memorial telescope with the hope of obtaining a photograph of the meteor swarm as a cluster or comet outside our atmosphere. This camera was the chief hope of the watch on the morning of the 16th, for which Dr. Johnstone Stoney had kindly provided the position for the sight-line-tangent to the meteor path. Unfortunately the sky, though clear enough for eye observation of meteors to the third magnitude, was too hazy for the feeble light of the distant swarm. Only a few *Leonids* were seen on the morning of the 16th, and the preceding nights, from the 10th to the 14th inclusive, were cloudy throughout.

The stellar spectrograph has been employed on all available nights, to continue the series of photographs intended for investigation of possible changes in the spectra of selected stars. But the work of measuring and mapping these has been interrupted by a corresponding work on the solar drawings of the last nineteen years.

Markree Observatory (Colonel Cooper's).

During the year 1899 the regular meteorological work of the Observatory has been carried on as usual, and the weekly and monthly returns have been made to the Meteorological Office, the Registrar-General at Dublin, &c.

Some observations have been made with the unifilar magnetometer and the dip circle; but the magnet house not having been yet erected, only preliminary work has been attempted.

The great telescope was unfortunately injured in the storm of January 12, and the damage done not being repaired till the end of August, the instrument has only been used for a small part of the year. Some use has been made of a smaller instrument, and observations for the determination of local time have been regularly made with the meridian circle.

A few visitors have called at the Observatory, and some returns of the rainfall have been made in connection with proposed hydraulic engineering work in the neighbourhood.

The library is now in fair order and has been enriched by valuable presents during the year, for which best thanks are due to the donors.

A watch was made for the *Leonids* during several nights, but the sky was almost completely overcast, so that none were

certainly seen, although a few were reported to have been seen from Sligo on the early morning of November 15. The lunar eclipse of December 16 was for the same reason unobservable. The month of December 1899 was perhaps that of the greatest rainfall for many years.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

Astronomical and meteorological observations have been carried on as in past years. The phenomena of *Jupiter's* satellites, and the physical features of *Jupiter* and *Mars*, have been carefully and regularly observed; the results have already appeared in the *Monthly Notices*. The usual 9 A.M. and 3 P.M. meteorological observations have been made, and reports or summaries sent to the Registrar-General, Mr. Symons, local newspapers and occasional applicants.

Wolsingham Observatory (Rev. T. E. Espin's).

The work has been carried on as in previous years. The results of the sweeps are as follows :—

Stars of type IV.	5
„ „ III. ! ! III. ! ! !	86
„ „ II. III. !	155
Known stars observed	126
New nebulæ	6

Various plates have been obtained with the 8-inch photographic telescope, and in the latter part of the year measures have been made of some double stars and some new pairs.

Sir William Huggins's Observatory, Tulse Hill.

The photography of the spectra of stars, which has been in progress for some years, has been continued.

Special work has been done in the laboratories in connection with the completion of a volume of publications of this Observatory, which is just ready, and of which the principal contents are an Atlas of representative stellar spectra from λ 4870 to λ 3300; together with a discussion of the evolutional order of the stars, and the interpretation of their spectra; preceded by a short history of the Observatory and its work.

Rousdon Observatory (Lyme Regis), Devon (Sir Cuthbert E. Peek's).

The building and equipment of the Observatory have been maintained in their usual order. November was an abnormally cloudy month, the rest of the year was generally favourable, and observations were made on 167 nights, this being about the average. The 6·4-inch Merz equatorial has been kept at the regular observation of long-period variable stars; Argelander's method was followed as during the previous thirteen years. Five hundred and seventy magnitude determinations have been made, being in excess of any previous year's work. Seventeen maxima and twenty-two minima have been observed. As most of these variables at minima are very faint objects, and as several fall below 13·5 magnitude, thus being beyond the range of this telescope, the observations have been very difficult. About twenty-five variables of long period are under regular observation; these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 4, containing observations of *R Cygni* and χ *Cygni* for the ten years 1887 to 1896, and *Variable Star Notes* No. 5, containing observations of *U Orionis* and *S Herculis* for the thirteen years 1886 to 1898, have been published and distributed. The results are given concisely in tabular form, accompanied by diagrams of the light curves.

Variable Star Notes No. 6 is far advanced, and will appear shortly.

Transits of stars have been taken as often as required for the timing of the sidereal clock, which has maintained a very steady rate.

Birr Castle Observatory (the Earl of Rosse's).

During the past year determinations of the Moon's radiant heat have been continued at intervals, in order to arrive at a better phase-curve than had up to the present been found possible, but the difficulties arising from climatic and other causes make our progress extremely slow.

It has also been necessary to wait for lunar eclipses to clear up uncertain points. Some determinations made during the eclipse of 1898 December 27, now being reduced, will be, owing to clouds, necessarily of inferior value to those obtained on previous occasions. "Near approaches" were watched for on 1899 January 26, April 25, July 22, and October 18, but without success, owing to the same cause. The same may be said of the eclipse of December 16.

Some photographs of nebulæ have been taken, but the results have not been as satisfactory as might have been expected, from causes which would take too long to explain here.

Meteorological observations have been continued as usual.

The *Leonid* meteors were watched for, but fewer than usual seen when occasional breaks in the clouds rendered this at all possible.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The second volume of photographs of *Stars, Star-clusters*, and *Nebulæ*, to which reference was made in my report to the Council in February last, is now printed; and before this report is read about one hundred copies will have been presented to a select number of public Observatories, Institutions, Societies, and to some astronomers.

Attempts were made in November and December to photograph the *Leonid Meteor Stream*, the positions of which were given in the Ephemeris furnished by Dr. G. Johnstone Stoney and Dr. Downing, aided with the grant made by the Royal Society; the computations for which were made by Mr. Thomas Wright, of the staff of the *Nautical Almanac* Office.

Two opportunities occurred that were suitable for taking photographs. The first on November 6, when plates were taken with an exposure of ninety minutes; the second on November 8, with an exposure of two hours and fifty-five minutes. Three photographs were taken simultaneously on each occasion: one with the 20-inch reflector, one with the Cooke 5-inch lens (aperture to focus 1 to 3·84), and the other with a Voigtländer lens (aperture 1 to 2·2); but on none of these six photographs was there any indication of the presence of the meteor stream.

Close watches were also kept on the sky each night and morning between 11 P.M. on November 14 and 5.30 A.M. on the 17th, with the object of finding an opportunity for photographing the meteor trails as they would be formed in the atmosphere; but the sky was either continuously obscured by clouds, or else with a few clear openings of short duration. No chance for obtaining a photograph occurred during those four days; consequently all the attempts were failures.

The selected photographs of celestial objects referred to as follows have been taken during the past year; which, like most of the preceding years, has generally been unfavourable for photographic work.

List of the principal Photographs taken in 1899.

	R.A. h m	Decl. ° ′	Expos. h m	
ℌ's Nebulous Region No. 2 ...	0 17	+ 3 59	1 30	
„ „ „ „ 3 ...	0 22	+29 0	1 30	
„ „ „ „ 6 ...	0 36	+ 0 29	1 30	
Neb. M. 31 Andromedæ	0 37	+40 43	1 30	(three)
Neb. ℌ V. 1 Ceti	0 42	−25 51	1 30	(two)

	R.A. h m	Decl. ° ′	Expos. h m
Neb. near γ Cassiopeiæ	0 50	+60 11	1 30
Neb. M. 33 Trianguli	1 28	+30 8	1 30
Nebulosity in Pleiades region ...	3 44	+25 16	2 58
Neb. ♅ I. 258 Persei	3 55	+51 1	2 52
Hind's neb. in Taurus	4 16	+19 17	1 30
Neb. ♅ I. 122 Eridani	4 36	− 3 3	2 54
Neb. ♅ V. 32 Orionis	5 1	− 3 30	2 20 1 30
Neb. ♅ V. 38 Orionis	5 21	− 8 13	1 30
Neb. N.G.C. 2237 &c. Monocerotis	6 25	+ 5 0	1 30 2 45
New Nebula in Monoceros ...	7 0	−10 20	2 47
Neb. ♅ V. 21 Canis Majoris ...	7 12	−13 1	1 30
Cl. M. 67 Cancri	8 45	+12 13	1 0
Neb. ♅ I. 72 Ursæ Majoris ...	10 23	+30 2	1 30
Neb. ♅ I. 81 Leonis	10 38	+25 29	1 30 2 47
Neb. ♅ V. 52 Ursæ Majoris ...	10 40	+63 47	1 30
Neb. ♅ I. 172 Ursæ Majoris ...	10 46	+37 11	1 30
Neb. ♅ I. 87 Leonis Minoris ...	10 54	+29 33	2 40
Neb. ♅ I. 194 Ursæ Majoris ...	11 20	+44 10	2 47
Neb. ♅ I. 203 Ursæ Majoris ...	11 47	+44 43	2 32
Neb. M. 99 Virginis	12 13	+14 58	1 30
Neb. M. 61 Virginis	12 16	+ 5 3	2 3
"Leonid" meteor swarm	13 10	+ 9 38	4 0
" " "	13 16	+ 8 37	2 0
Neb. ♅ I. 170 Boötis	13 41	+42 15	1 30
Neb. ♅ I. 180 Boötis	13 42	+44 22	1 30
Neb. ♅ I. 181 Boötis	13 53	+42 22	1 30
♅'s Nebulous Region No. 40 ...	14 2	+34 8	1 30
Neb. ♅ I. 214 Ursæ Majoris ...	14 2	+54 40	1 30
♅'s Nebulous Region, No. 41 ...	15 9	+18 57	1 30
Neb. ♅ II. 759 Draconis	15 13	+56 43	2 0
Neb. ♅ I. 148 Scorpii	15 17	+ 5 27	2 0
Cl. M. 80 Scorpii	16 11	−22 43	1 30
Cl. ♅ VI. 40 Ophiuchi	16 26	−12 50	1 0
Neb. ♅ I. 280 Ursæ Minoris ...	16 38	+78 25	2 0
Neb. ♅ IV. 41 Sagittarii	17 56	−23 2	1 30
Neb. M. 8 Sagittarii	17 57	−24 23	1 30
Neb. M. 17 Clypei	18 15	−16 13	2 18
Cl. M. 22 Sagittarii	18 30	−24 0	1 30
Neb. M. 27 Vulpeculæ	19 55	+22 26	0 50
Cl. M. 75 Sagittarii	20 0	−22 13	1 0
Cl. M. 73 Aquarii	20 53	−13 2	1 0
♅'s Nebulous Region No. 47 ...	21 5	+14 21	1 30
Cl. M. 2 Aquarii	21 28	− 1 16	1 18 1 30
♅'s Nebulous Region No. 49 ...	21 47	+21 31	1 30

Mr. W. E. Wilson's Observatory, Daramona, Streete, co. Westmeath.

During the past year the 24-inch reflector has been used almost entirely for stellar photography. During the summer one of Ångström's pyrheliometers was ordered from Messrs. Sandstrom, of Lund, but was not received until late in the year. From a few observations taken with it in December, the instrument seems to give very concordant results of the value of solar radiation in absolute units.

Hong Kong Observatory.

Hourly meteorological observations, weather reports, storm warnings, magnetic observations, tabulation of meteorological logs kept over the eastern seas, the time service, &c., were continued as in previous years. Variable stars, shooting stars, and the Zodiacal Light were only occasionally observed. About 5000 transits were observed.

The re-reduction of Sir J. Herschel's sequences of southern stars was finished, and we now possess a catalogue of accurate magnitudes of 918 stars for 1837. Very few observations of known variables are included. The probable error of an observation of a star of the 2nd magnitude is $\pm 0{\cdot}075$; of the 3rd, $\pm 0{\cdot}087$; of the 4th, $\pm 0{\cdot}121$; and of the 5th, $\pm 0{\cdot}204$.

A star of the 1st magnitude was on an average observed 11 times by Sir J. Herschel, of the 2nd 8, of the 3rd 3, of the 4th twice, of the 5th $1\frac{1}{2}$ times, and of the 6th only once.

The Madras and Kodaikánal Observatories.

On April 1, the beginning of the Indian financial year, the reorganisation of the Madras Observatory, which has for some time been decided upon, took effect. The Observatory, which has ever since its foundation in 1792 been directly under the Madras Government, was handed over to the Government of India, and the former "Government Astronomer" became the "Director of the Kodaikánal and Madras Observatories." At the same time the headquarters of the Director were transferred to Kodaikánal, and the Madras Observatory was placed under the charge of Professor R. Ll. Jones as Deputy-Director.

Advantage was taken of the dry weather of the first three months of the year to move up to Kodaikánal the instruments and the astronomical library—a matter of no small difficulty, since for ten miles of the road everything had to be carried by coolies up a steep and narrow path. Including furniture, more than 1000 coolie-loads were brought up.

Almost the whole of the Director's time during the past year has had to be devoted to matters concerned with the new buildings. At the close of the year both domes were erected and the 6-inch equatorial was in place, though not finally adjusted. Much work yet remains to be done on the buildings, and at the present rate of progress it will be several months before the workmen have finished the main building.

No astronomical observations, except those on the *Leonids*, have been attempted during the year at Kodaikánal, but the printing of the star catalogue has been completed, and the volume should be ready for distribution in a few days. Meteorological observations were begun on April 1, and have been continued regularly.

At Madras the usual time observations and distribution of time signals were continued, as well as the meteorological observations.

Melbourne Observatory.

Meridian Observations.—These were made with the 8-inch transit circle. The table below shows their distribution :—

Observations in	R.A.	N.P.D.
Azimuth Stars	334	168
List "	1166	1171
Clock "	812	...
Dr. Gill's "	825	1010
Total	3137	2349

The list stars were selected from the Melbourne photographic plates of the catalogue series, and are to be used as fundamental stars for the reduction of these plates. Dr. Gill's stars are those given in his printed list of "Heliometer Comparison Stars, 1898–1900."

Astrophotographic Work :—

Chart plates with single exposure of 60^m... ...	189
Catalogue plates (second series)	30
Test plates for transparency of night	48
Test plates Oxford type regions	24
Test plates for trails, centre, &c.	31

Fifteen chart plates were rejected as defective.

A second series of catalogue plates especially for zones nearer to the Pole is gradually being obtained. The series of chart plates for even degrees of declination with single exposure of one hour is very nearly complete, and we are now proceeding with the series for odd degrees of declination with three exposures of 30^m each.

With the photoheliograph 21 pictures of the Sun were taken on special occasions.

Time signals for determining the difference of longitude between Perth and Melbourne were exchanged on the night of September 28.

Only a few occasional observations were made with the great telescope and other equatorials, but no regular work was done with them.

The time service, including rating of chronometers for the shipping, &c., was carried on as in former years.

The meteorological service has been the great burden of the Observatory, and is continuously increasing. The number of recording stations in the Colony of Victoria is now about 600.

The photographic registration of the variation of the magnetic elements and their absolute measurements, cloud photography for the determination of height and velocity of clouds, and the testing of meteorological and nautical instruments for the public, have formed part of our routine work during the year.

Three hundred and eight visitors were shown over the Observatory on Wednesday afternoons, and 248 were admitted on specially appointed nights.

Five young computers were employed in the course of the year in measuring and reducing magnetic curves and cloud photographs, and in preparing the third Melbourne General Catalogue of stars for the epoch 1890, which will contain some 3000 stars observed with the 8-inch transit circle during the years 1884–1893 inclusive.

Sydney Observatory.

In the report for 1898 it was stated that arrangements had been made for the removal of the star camera to Red Hill, 615 feet above the sea, and 11½ miles to north-west. This work had been completed in August of this year, and since that date the instrument has been used on all available nights. As a measure of the relative clearness of the atmosphere at Red Hill and Sydney, it may be mentioned that with an equatorial of 7½ inches diameter in use at Red Hill one can see more details of planetary markings than it is possible to see in Sydney with an equatorial of 11½-inch aperture.

The joint bureau for the measurement of the star plates has been established in Melbourne. (For the joint report, see next page.)

Transit Circle.—With the transit circle (one observer) 938 transits of stars and 511 meridian zenith distances have been observed, and the Sun has been observed on all available days for time, distributed by time balls and signals. Collimation level and nadir have been regularly observed, and show the regular seasonal and secular changes in the Observatory hill.

Equatorial.—With the equatorial measures of double stars have been made on eighty-four evenings; six nights were devoted

to comet observations. One hundred and twenty-nine pairs (double stars) were measured; 114 of these are remeasurements of pairs in the Sydney lists of 1882–3. Six hundred and sixty-one settings for position angle and 662 for distance were made during the year. Twenty-five comparisons of Comet Swift were made with five stars.

Leonid Meteors.—A careful watch was kept by many observers in this colony for the November meteors, but, unfortunately, on the nights of the 15th and 16th it was densely cloudy in Sydney and greater part of this colony.

Star Camera.—The time necessarily occupied in removing the star camera to Red Hill seriously interfered with the work during the year. One hundred and fifty-three days were wet or cloudy, and 120 days were occupied in removing the instrument to Red Hill. During the year seventy-two catalogue plates and fifty-three chart plates were taken.

Publications.—During 1899 2067 copies of books and pamphlets were sent out, and in exchange 669 books and pamphlets have been received and acknowledged.

Meteorology.—Meteorology continues to demand a large part of our time. The number of observers has increased from 1610 in 1898 to 1724 in 1899.

Measurement of the Sydney and Melbourne Plates of the Astro-photographic Catalogue.

(Joint Report by the Directors of the Sydney and Melbourne Observatories.)

These measurements have been carried on at the Melbourne Observatory in accordance with the conditions, a brief mention of which was made in *Monthly Notices* for February 1898. Three measuring instruments were employed, consisting principally of filar micrometer microscopes mounted on heavy cast-iron stands, which also carry a stage for the plates, with double slide motion in two directions at right angles to each other. The resulting measures are well within the prescribed limit of error $0''\cdot2$; but the methods of observation are excessively slow, the average number of stars measured in one position of the plate by a single observer without the assistance of a recorder being about fifteen per hour. Professor Turner's micrometer scale can be used with our present instruments instead of the filar micrometers, and with this scale some 300 stars can be measured in one day by two persons acting alternately as observer and recorder; but in our experience the probable error of the resulting measures exceeds $0''\cdot5$, and consequently the use of the micrometer scale was abandoned.

A measuring instrument similar to that devised by Dr. Gill for the Cape Observatory was ordered from the firm of Repsold &

Söhne early last year, and has just arrived here safely and in good order. It corresponds in all its parts to the description given by Dr. Gill in *Monthly Notices*, vol. lix. p. 61, excepting that the two slides of the micrometer carry only a pair of webs each, instead of a series of six webs for each slide, as in Dr. Gill's instrument. Nothing can be said at the present moment as to the qualities of this new machine, as there has not been time yet for careful examination and actual trial. A measuring machine devised by Mr. Russell, quite on a different principle from those we now possess, is being made in Sydney under his supervision. In all 50 plates have now been completely measured, and it is to be hoped that with the new machines good progress will be made during the current year.

Natal Observatory.

During the year the observations have been confined almost entirely to those necessary for carrying on the ordinary routine astronomical and meteorological work of the Observatory. Some observations of comets and of *Eros*, together with a number of observations of occultations during the Lunar Eclipse, were also obtained. No *Leonids* were visible.

Practically the work of the Observatory must be confined to mere routine time and meteorological observations, as since the vote assigned to the Observatory was reduced it is no longer sufficient to pay even the salaries of the assistants, the balance, together with all other expenses, having to be defrayed by the Astronomer.

During an exceptional storm in November, a portion of the library was flooded and much damage done, especially to the manuscripts. Amongst those which were seriously damaged and will have to be rewritten before being printed were our Star Catalogue, the reduction of the Greenwich Lunar Observations for 1750–1895, and the New Lunar Tables for supplementing Hansen's *Tables de la Lune*. It will take over a year to rewrite these for the press.

Perth Observatory, Western Australia.

The work of the Observatory has been so far mostly meteorological. Records of barometer, temperature, &c., have been kept at many stations throughout the colony for a number of years, and these had not been properly reduced and entered in ledgers. This work is now nearly completed; and, in addition to the current meteorological work, has occupied the full time of the staff, which is very small. The forecasts have again been very successful. Of these one is issued daily at noon, and another is contributed to the Press every evening, based upon reports

received at 6 P.M. from thirteen selected stations, and published in the daily papers. A special forecast for the Goldfields is also prepared each evening, and telegraphed to four daily newspapers on the Fields.

The percentage of success for the year was :—

	Noon.	Evening.	Goldfields.
Correct	82	89	90
Partially correct	17	11	8
Wrong	1	0	2

A local forecast for the day is issued at 9 A.M., and exhibited in a pictorial form similar to that of the London *Daily Graphic.* This is almost invariably correct.

The transit circle and astrograph are now ready for work, and observers have had a fair amount of training; but, owing to a recent decision of the Government, it will not be possible at present to do much with them. The transit circle will be used only for time and determination of position of a guide star for each plate of the zone 17° to 23° S. Work with the astrograph will be commenced very shortly, but, owing to lack of observers, progress just at present will be slow.

Instead of taking up the zone 17° to 23° vigorously with both instruments, as the Government Astronomer hoped to be able to do, he has been instructed to defer that for the present, and to admit pupils training as surveyors or navigators to a course of practical astronomy. However, he intends, if possible, to carry on the above scheme as well, but it is a little doubtful to what extent this will be practicable.

Lovedale Observatory, South Africa (Mr. A. W. Roberts's).

The main work of this Observatory is the observation of variable stars south of −30° decl.

This work was carried on regularly during the year, the number of observations secured being as follows :—

	Stars.	Observations.
Algol variables	6	674
Short period variables	23	1873
Long period variables	74	2941
Suspected variables	10	120
Total	113	5608

The reduction of all observations taken since 1891 is being proceeded with, but the pressure of other concerns has lately hindered the completion of this task. The same circumstances have compelled the laying aside, during the past four or five months, of the magnitude survey entered upon last year.

The Director has gratefully to acknowledge the generous gift to the Observatory of an equatorial, a sidereal chronometer, and a dome from Sir John Usher, Norton, Edinburgh. The equatorial, of 2-inch aperture, is specially constructed by Messrs. T. Cooke & Sons for the visual determination of star magnitudes; a large prism in front of the object glass permits of the field under examination being rotated through any angle, and the aperture can also be "stopped" down to any size. Lord Maclaren and Dr. Gill have warmly interested themselves in the new observatory and its equipment.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

The weather during 1899 was favourable for astronomical work. The following is the work in the meridian department for the determination of local time:—

Nights on which the time was determined	... ...	195
Observations of stars with a declination not exceeding 40°	...	975
Observations of stars in high declination for azimuth ...	...	237
Separate determinations of	level error	575
	collimation error	51
	azimuth error	170

In the extra-meridian department the following comparisons of planets and comets were made with the equatorials:—

Object.	Nights of Observation.	Number of Comparisons.	Number of Comparison Stars.
(4) Vesta	7	81	1
(7) Iris	30	380	17
(17) Thetis	16	204	3
Neptune and 114 (*o*) Tauri ...	6	80	1
Comet VII., 1898 (Coddington)...	23	152	33
Comet I., 1899 (Swift)	28	233	35
Comet IV., 1899 (Tempel$_2$, 1873)	43	413	51

The observations of Comet 1898 VII. were a continuation of the series commenced on 1898 June 15, and carried down to the close of that year. The total number of nights on which the comet was observed in 1898 and 1899 was 103, the number of comparisons being 764, and that of the comparison stars 138. Comet 1899 IV. was observed on all possible occasions at the request of M. Schulhof, of Paris. In addition to the above observations 78 phases of lunar occultations of stars were ob-

served, eighteen of them during the total eclipse of the Moon on June 23. Mr. C. T. Merfield, F.R.A.S., kindly supplied a list of occultations for the eclipse. Most of the stars were, however, taken from the Cape *Photographic Durchmusterung*, and were very faint. The same gentleman has also given an excellent ephemeris of Comet 1898 VII., and comparisons of the planet and comet places with the ephemerides. Observations of phenomena of *Jupiter's* satellites and a few measures of double stars were likewise made during the year. The meteorological observations referred to in the report for 1898 have also been continued through 1899. By comparison with former reports it will be seen that the work during the past year is quite equal to that in any former year.

Notes on some Points connected with the Progress of Astronomy during the Past Year.

Discovery of Minor Planets in 1899.

Twelve new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Date of Discovery, 1899.	Discoverer.	Place of Discovery.
EE	442	Feb. 15	Wolf—Schwassmann	Heidelberg
EF	443	„ 17	„	„
EL	444	March 31	Coggia	Marseilles
EM	...	April 5	Witt	Berlin (Urania Obs.)
EO	...	July 17	Wolf	Heidelberg
ER	...	Oct. 27	Wolf—Schwassmann	„
ES	...	„ 27	„	„
ET	...	„ 27	„	„
EU	...	„ 31	„	„
EV	...	„ 10	„	„
EX	...	„ 2	Coddington	Lick Obs. (Mt. Hamilton)
EY	...	Dec. 4	Charlois	Nice

The planets provisionally designated EG, EJ, EK, EN, EP, EQ, EW, EZ were identified as follows .—

EG with	(224) *Oceana*,	EP with	(32) *Pomona*,
EJ „	(60) *Echo*,	EQ „	(161) *Athor*,
EK „	(222) *Lucia*,	EW „	(110) *Lydia*,
EN „	(85) *Io*,	EZ „	(415).

The announcement of the discovery of EH was cancelled as erroneous.

ER has an orbit resembling those of the missing planets (99) *Dike*, (155) *Scylla*, and it may possibly be identical with one of them.

EV was at first supposed to be identical with (214) *Aschera*, which was the reason of the delay in the announcement of its discovery.

The following planets, discovered in 1898, but not numbered at the date of the last report, have since received permanent numbers: DP, 437; DU, 438; EB, 439; EC, 440; ED, 441.

The planets provisionally designated DV, DW, DX, DY, DZ, EA, EM do not receive permanent numbers, not having been sufficiently observed.

The following planets have been named: (355) *Gabriella*, (366) *Vincentina*, (387) *Aquitania*, (439) *Ohio*.

The following planets have been observed at one opposition only: 99, 132, 155, 156, 157, 193, 220, 285, 290, 293, 296, 309, 310, 314, 315, 316, 319, 320, 323, 327, 328, 330, 341, 353, 355, 357, 359, 360, 361, 368, 382, 383, 388, 392, 393, 394, 395, 398, 400, 401, 406, 408, 410, 411, 413, 414, 417, 418, 421, 422, 425, 426, 427, 428, 429, 430, 431, 432. All the other planets, from 1 to 434 inclusive, have been observed at two or more oppositions.

The planet (433) *Eros* remained under observation till May last, a period of nine months from its discovery. As it receded from the Earth, it approached the Sun, and consequently its brightness remained nearly constant during this period. Signor Millosevich has computed definitive elements from all the observations of this period, but without making use of the photographs of 1893–94, 96 (*Ast. Nach.* 3609). He deduces the following elements for the next opposition after applying planetary perturbations:—

$$\text{Epoch} = 1900 \text{ Oct. } 31^{\text{d}}{\cdot}5, \text{ Berlin M.T.}$$

$$\begin{aligned}
M &= 304^{\circ}\ 23'\ 59''{\cdot}7 \\
\left.\begin{aligned}
\pi &= 121\ \ \ 9\ 22{\cdot}0 \\
\omega &= 177\ 38\ 41{\cdot}6 \\
\Omega &= 303\ 30\ 40{\cdot}4 \\
i &= \ \ 10\ 49\ 38{\cdot}9
\end{aligned}\right\}& \ 1900{\cdot}0 \\
\phi &= \ \ 12\ 52\ 48{\cdot}2 \\
\mu &= 2015''{\cdot}1274 \\
\log a &= 0{\cdot}1638027
\end{aligned}$$

He gives an ephemeris from 1900 September 1 to 1901 January 31. It does not differ by more than 23^{s} of R.A., $6'$ of decl., from the approximate ephemeris given in the last report. He again calls attention to the fact that the large phase of the planet may cause systematic errors in parallax measures unless special precautions are taken.

The planet will be nearest to the Earth on December 26 next, when its horizontal parallax will be $27''{\cdot}9$. There will not be an equally near approach for about thirty years. It is interesting

to note that *Eros* and *Mars* approached one another within a distance of 0·28 in 1899 October. This is very little greater than the least possible distance of the two planets, which is 0·24. As their synodic period is no less than 27·59 years, such a close approach is rare. A. C. D. C.

The Comets of 1899.

In addition to several comets mentioned in the last Annual Report, observations of which were continued into the year 1899, two new ones have been discovered, and three periodical comets have been detected on their return to perihelion.

On March 3, Professor Lewis Swift, at the Lowe Observatory, perceived a fairly bright comet as it was approaching perihelion, which it passed on April 13. The position at the time of discovery and shortly after was not very favourable for observation, but after perihelion passage it attained a very considerable northern declination, and became a fairly conspicuous object. At the time of greatest brilliancy the naked eye view was not unlike that of a hazy star of the third magnitude, while in the telescope the tail could be traced for more than a degree. Photographs, however, showed this tail much longer, Professor Barnard tracing it on a plate taken on May 18 to a distance of 8° from the nucleus. The decrease in brilliancy seemed rather rapid, but by no means regular. Early in June a notable increase in lustre was announced by several observers, though the estimates of magnitude considerably differed. In the second week of May Mr. Perrine announced that the nucleus had duplicated, a fact which was confirmed by Professor Barnard, and the increase of brilliancy may very well be connected with this display of internal energy. An admirable series of photographs, showing the changes in the form and extent of the tail, was obtained at the Lick Observatory. The orbit is probably parabolic.

Dr. Wolf, of Heidelberg, detected on March 5 the trace of Tuttle's periodic comet on a photograph of the district in which the comet was known to be situated. The circumstances of the return had been computed by Dr. Rahts, and the agreement between the observed and computed place was satisfactory, considering the small number of observations that were made on the last return in 1885. On that occasion the same computer had assigned a place whose error in Right Ascension was $12^s.6$, and in Declination 5′36″. On the present return the discrepancy between observation and computation was 22^s of R.A. and 5′ in Declination. It is to be hoped that the observations which have been made will be sufficient to give an improved value of the mean motion, but for observers in the Northern Hemisphere the comet was soon lost in the evening twilight. After perihelion (May 4), however, the comet could be observed in the Southern Hemisphere, and would be slightly brighter.

This is the fourth successive return at which the comet has been visible.

The third comet of the year was also one of the periodic class, viz. that known as Tempel's Second Comet (1873 II.). This object was detected by Mr. Perrine at the Lick Observatory on May 6. On that date the theoretical brilliancy of the comet was expressed by 0·49. In 1878, when the comet was bright enough to be seen by M. Tempel, the brilliancy was only 0·113; and in 1894, when first seen by Mr. Finlay at the Cape, the value was 0·190. The comet has always been faint, and these figures show that it tends to become fainter still. But the circumstances of the return were generally favourable for observation, and a steady increase in lustre was easily noticeable. Mr. Perrine described the object at the time of discovery as approximately of the fifteenth magnitude, but by the middle of July it was a fairly easy object in a 6-inch telescope. Dr. Wolf, who photographed the comet on the same plate with the planets *Euterpe* and *Antiope*, found the traces of the comet comparable with those produced by these planets, thus giving a magnitude of about 10·7. A short diffused tail pointed towards the North was noticed on the photographic plate.

The orbit did not suffer such great perturbation as on some previous occasions, the distance of the comet from *Jupiter* being always greater than 1·9 R. Nevertheless, the passage through perihelion was delayed fifteen days; and since the alteration of the other elements was considerable, we can heartily congratulate M. Schulhof on the accuracy of his prediction, which assigned a place to the comet differing only 6 secs. in R.A., while the error in Declination was within the errors of observation. A correction to the mean anomaly of $-24''$, or an alteration in the time of perihelion passage of less than an hour, would satisfactorily remove this small discrepancy.

Holmes' Comet of 1892 passed its perihelion passage on April 13, but was not found till June 10, when Mr. Perrine, aided by the large telescope of the Lick Observatory, added another to his many cometary discoveries. This comet, like the last, was described as of the sixteenth magnitude, and though the brilliancy was slightly on the increase, it is to be feared that not many observations have been secured. So far as at present known, the observations that have been made have been confined to the two great American refractors. Dr. Zwiers was responsible for the ephemeris which led to the detection of this interesting comet; and considering that this is the first return since the discovery, the closeness of the prediction is quite satisfactory. The period had been determined within less than half a day, giving rise to an error in the ephemeris of -22^s in R.A., and $-4'$ in Declination. It is much to be hoped that the number of observations made at this return will be sufficient to improve the theory of the comet's motion.

On September 30 M. Giacobini discovered a telescopic comet in *Ophiuchus*, moving northward. The perihelion passage had been passed on September 14, and since the distance from the Earth was also increasing, the comet remained a feeble object. The orbit will probably prove parabolic, but definitive elements are not yet known. W. E. P.

Meteoric Observations during the Year.

The January and April meteors were not satisfactorily observed, owing to moonlight and cloudy weather. Professor Herschel, at Slough, watched on April 16, 17, and 19, but noticed little radiation from the usual contemporary showers in *Virgo*, *Scorpio*, *Aquila*, &c. There was, however, an active radiant in *Canes Venatici*.

On clear nights between May 3 and 7 Professor Herschel made observations extending in the aggregate over sixteen hours, and found radiants at $175°+30°$, $315°-10°$, and $336°-6°$, the latter representing the *Aquarids* and the special shower of the epoch. During the same period Mr. E. R. Blakeley at Dewsbury noted seventy meteors in watches amounting to ten hours, and derived radiants at $255°+37°$, $218°+24°$, $232°+23\frac{1}{2}°$, and $267°+50°$, but apparently registered no *Aquarids*.

August Perseids.—Splendid weather favoured views of this shower, and observations were obtained at many places on August 9, 10, 11, 12, 13, and 14. The display was not an exceptionally rich one, and certainly did not at any time equal the strength it exhibited on 1898 August 11. The hour of maximum is doubtful. Professor Herschel of Slough, and Mr. T. H. Astbury of Wallingford, recorded more meteors on August 10 than on August 11, but M. Antoniadi at Juvisy, Mr. Gregg at Malvern, and Mr. Milligan at Belfast, found the largest number visible on August 11. M. Wolf at Königstuhl, and Mr. Denning at Bristol, concluded that meteors were about equally frequent on the two nights. On August 11, from 11^h to $11^h\ 30^m$ (local time) at Belfast meteors were falling at the rate of about sixty per hour. On August 11, $14^h\ 10^m$ to $14^h\ 15^m$, Mr. King at Leicester estimated the rate at eighty-four per hour, of which sixty were *Perseids*. A large number of secondary showers became apparent during the observations. Mr. Besley, of Clapham, S.W., found the ζ *Cassiopeids* $(4°+52°)$ very active. Mr. Bridger, of Farnborough, saw the ϵ *Cassiopeids* $(17\frac{1}{2}°+58°)$, as did also Mr. A. King, of Leicester $(21°+60°)$. At Bristol the best shower was from *Draco* at $277°+70°$. The position of the main radiant point of the *Perseids*, as observed during the first half of August, showed the usual motion to the eastward, but there were comparatively few observations before August 9. On the following six nights the mean places of the radiant, from

observations by Antoniadi, Besley, Bridger, King, and Denning, were as follows:—

		α δ		
		° °		
August 9	...	43·3+56·5	...	3 radiants
„ 10	...	44·4+56·9	...	5 „
„ 11	...	45·5+56·9	...	5 „
„ 12	...	46·9+57·2	...	5 „
„ 13	...	48·5+56·5	...	2 „
„ 14	...	50·3+57·2	...	3 „

At Bristol on August 16 seven *Perseids* indicated the radiant at 53°+57°. The displacement in the position from night to night is therefore shown in a very striking manner. From observations of this shower in and since 1893 our knowledge has been rendered pretty complete; but the display requires attentive watching in its earlier stages during the last half of July. A considerable number of *Perseids* were observed at more than one station, and several of the brighter examples are included in the table of real paths.

The Leonids.—Preparations were made everywhere to witness and suitably record the display of *Leonids* at the middle of November. The weather was partly clear at some places, but the shower failed to return in exceptional strength. The number of meteors seen did not exceed those counted in the few previous years at the same epoch, and the display fell below the average richness of the August *Perseids*. It was intended that photography should play an important part in accurately recording the flights of bright meteors near the radiant, but the attempts appear to have signally failed. At a few stations an isolated track was found on the plates, but the shower proved altogether too poor to give success either to the photographic or visual method. A vast number of reports have been received from England and foreign places, and they are in fair accordance. The maximum occurred on November 14, 17^h to 18^h G.M.T., when, however, the horary rate of *Leonids* visible for one observer scarcely exceeded twenty-five. There was a decided falling-off on the night following November 15 as compared with the number seen on the preceding night. From the rate of apparition given by several observers it would appear that *Leonids* were increasing when the morning twilight of November 15 terminated observations; but the descriptions from longitudes far west of Greenwich do not support the inference that a strong shower occurred after sunrise in England. In America the event was awaited with the same intense interest as in this country, but observations proved similarly disappointing, for the display was one of third-rate character. The maximum of the shower, such as it was, occurred both in 1898 and 1899 on the morning of November 15, though computations had indicated it about a day later. It

seems highly probable that 1899 was really too early to expect a visible return of the main swarm. There were brilliant displays in 1866, 1867, and 1868, and a recurrence of the first of these would not be due in 1899 November by several months if the period is about 33·3 years. The middle of the swarm probably came in 1867, and our prospects for 1900 and 1901 are certainly more inviting than they were in 1899, unless indeed the major planets have disturbed the orbit in sufficient degree to enable the richest part of the group to escape contact with the Earth.

The Andromedids.—Perhaps the most interesting meteoric event of the year was the occurrence of a well-marked, if not very brilliant, shower of the meteors associated with Biela's comet. Near Vienna Dr. S. Oppenheim and several other observers watched the display on November 23, and between $4^h\ 56^m$ and $8^h\ 36^m$ G.M.T. counted sixty-five meteors. On November 24, between $7^h\ 56^m$ and $9^h\ 26^m$, they counted 240 meteors. The maximum was at about 7^h, when meteors were falling at the rate of about ninety per hour. On November 23, $8^h\ 21^m$ G.M.T., a large fireball was seen passing from $100° + 10°$ to $90° + 0°$. Professor C. A. Young, at Princeton, N.J., says that on November 24, for a short time about 15^h G.M.T., the number of meteors observable by a single person was two or three a minute. After 16^h, only three meteors appeared in fifteen minutes. The place of the radiant was estimated at $23° + 42\frac{1}{4}°$. "It was obviously not a point, but an area 2° or 3° in diameter." At Northfield, Minn., Professor H. C. Wilson and several other observers saw a considerable number of meteors on November 24. A systematic watch was not commenced until about $16\frac{1}{4}^h$ G.M.T., when in the first five minutes one observer saw ten *Andromedids.* The shower was nearly over an hour later. The place of the radiant was one-third of the way on a line from γ to ϕ *Andromedæ.* At Boston, Mass., Mr. R. M. Dole watched from $11^h\ 40^m$ to $14^h\ 42^m$ G.M.T., and counted sixty-four *Andromedids*, eleven *Taurids*, and other meteors. In a diagram in *Popular Astronomy*, 1900 January, he puts the radiant close to β *Andromedæ.* Dr. Villiger at München, Germany, observed a few meteors of the shower on November 23 and 24, and placed the radiant at $1^h 17^m{\cdot}5 + 37°$. In England the weather was not very favourable, but at Norwich Mr. Willis counted sixty-two meteors between 10^h and $11^h\ 25^m$, and of these fifty-two were probably from *Andromeda*, but he does not give the place of the radiant (*Nature*, December 7). The Earth appears to have passed through the extreme rear end of the shower at its recent appearance, and a brilliant return may be expected on 1905 November 17 or 18, when we are likely to encounter a region of the swarm much nearer the remains of the parent comet.

Professor Herschel, in a series of watches extending over twelve hours on November 6–16, recorded five *Leonid* and sixty-nine non-*Leonid* meteors, and made a careful investigation (*Nature*, 1900 January 4) of the contemporary showers of the

epoch. He found radiants at $52°+8°$, $68°+17°$, $121°-1°$, $134°+67°$, and $143+29$.

The following is a list of the real paths of bright meteors observed in England during the past year :—

Date.		G.M.T.	Brightness.	Height at First.	Height at End.	Length of Path.	Velocity per Sec.	Radiant Point.	Observers.
1899.		h m		miles	miles	miles	miles	° °	
March	1	7 0	4 × ♀	73	28	53	21	119 + 31	3
	1	8 49	> ♀	58	22	39	10	119 + 33	3
April	4	7 59	2 × ♀	60	52	160	slow	202 − 10	3
June	2	8 47	♀	61	51	170	slow	250 − 23	4
Aug.	10	10 14	♀	76	40	54	v. swift	41 + 57	4
	10	10 54	♃	97	51	79	v. swift	45 + 58	4
	24	8 11	. ☽	77	27	118	17	345 + 14	49
	27	10 13	> ♀	68	47	143	25	191 + 32	6
Sept.	2	12 5	3 × ♀	86	60	28	swift	46 + 42	2
	4	8 13	♃ − ♀	67	21	52	34	311 + 79	2
	8	8 21	> ♀	71	26	114	20	347 + 3	2
Oct.	2	8 24	♀	67	45	88	13	284 − 17	3
Nov.	14	17 40	♀	71	42	46	swift	193 + 27	7
	15	16 48	> ♀	83	50	43	swift	150 + 20	4
	15	16 50	> ♀	82	45	49	swift	151 + 21	3
	19	8 5½	♃	85	42	68	23	60 + 28	2

W. F. D.

Solar Activity in 1899.

With the solitary exception of the numbers of the prominences, every class of solar phenomenon showed a diminished activity in 1899. Mr. Evershed reports that the mean number of prominences which he observed was almost precisely the same as in 1898, though their average size and extent were perceptibly diminished. Their distribution in solar latitude remained much the same, the southern hemisphere having a slight preponderance over the northern. The mean daily numbers of prominences seen in the two hemispheres are as follows :—

	1898	1899
North	3·32	3·27
South	3·65	3·73
Total	6·97	7·00

In each hemisphere there has been a well-defined limit in latitude, beyond which in the polar regions prominences have been rare and very small. This limit has been approximately :—

	1898	1899
North latitude	+56°	+54°
South latitude	−53°	−53°

Metallic prominences have been most infrequent; only five prominences having been seen in 1899, which reversed the lines of sodium and magnesium; and of these only one was north of the equator.

One large prominence of the eruptive class was observed on June 2 near the solar equator.

The change as to spots and faculæ has been most striking. The mean daily spotted area for 1899, to judge from the results as yet to hand, will not probably exceed 100 millionths of the visible hemisphere, as compared with 375 for 1898. M. Guillaume gives for the total spotted area for the first nine months of 1899 2980 units, as compared with 7951 for the previous year; a falling off of nearly 63 per cent. The same observer records almost as great a diminution of the faculæ; the area for the year just past being only 52 per cent. of that for the year which preceded it. The days when the Sun showed no spots have more than doubled in number, chiefly owing to a striking sub-minimum extending from July 17 to October 23, and there has been a complete absence of any really remarkable outburst; the last fortnight in March having shown the most noteworthy spot group of the year, and this at its greatest development only attained an area of 620 millionths. E. W. M.

Total Solar Eclipses.

No total solar eclipse took place during last year.

1898 *January* 22.

A few accounts of work done at this eclipse have been published, but the majority of observers have not yet completed the final reductions and discussions of their observations, so that we are not yet in a position to give any detailed statement of the results arrived at.

1900 *May* 28.

The preparations for this eclipse are well forward. The weather conditions in Portugal, Spain, and Africa appear to be favourable, though it is unfortunately not probable that the very exceptional clearness of atmosphere that was found in India in 1898 will be repeated. It is understood that the American astronomers are preparing for work in their continent with their usual energy, and should totality remain unobscured at both ends of the line, the comparison of the large scale corona photographs will be of considerable interest. E. H. H.

Astronomical Papers of the American Ephemeris.

During the past year Professor Newcomb has published tables of the heliocentric places of *Mars*, *Uranus*, and *Neptune*, thus completing his tables of the major planets. These conclude a

large and important section of the work which Professor Newcomb proposed to himself on his appointment as Superintendent of the American Ephemeris more than twenty years ago: "The ultimate problem in view was the construction of new theories and tables of the celestial motions generally, based on consistent values of the fundamental constants, which should themselves be determined from all the available data of observation."

The tables of *Mars* are similar to those of the Sun, *Mercury*, and *Venus*, of which an account is given in the Council Report for 1896. The method of formation of the tables of these planets is described in Professor Newcomb's *Elements of the Four Inner Planets and the Fundamental Constants of Astronomy.* The publication of the tables of *Mars* was delayed somewhat by apparent discordances between theory and observation; the most important discrepancy was traced to the fact having been overlooked that an inequality of the second order due to the product of the masses of the Earth and *Jupiter* is not contained in Leverrier's Tables. Professor Newcomb remarks that there are two questions which require further investigation: (1) the excess of the observed over the theoretical motion of the perihelion amounts to $6'' \pm 2''$ per century; (2) the determination of the mass of *Venus* by means of the term of long period (about thirty-three years, with amplitude $6''\cdot5$) in the motion of *Mars*.

The theory of the motion of *Uranus* and *Neptune* on which these tables are based is not yet published. The observations employed are those of the two planets made at Cambridge, Greenwich, Paris, and Washington, since the dates of their discovery down to the present time, along with Lalande's observations of *Neptune* in 1795. The mass of *Neptune* was derived from the measures of the satellite, and from the observations of *Uranus* from 1781 to 1896. The elements used in constructing the tables are given as affected by the long inequality of 4220 years, arising from the mean motion of *Uranus* being nearly twice that of *Neptune*. The form of the tables is slightly different from that used in the tables of the four inner planets, and, as in the case of the latter, is remarkably convenient for the computation of ephemerides. The residuals in longitude and parallax of *Neptune* are tabulated, but are not found to be of a systematic character such as would arise from the action of an unknown body.

The completion of the planetary tables affords a convenient opportunity for recapitulating the important series of papers which have up to the present time emanated from the office of the American Ephemeris, and most of which have been noticed in detail in previous reports of the Council (vols. xlii. xliv. xlv. xlvi. xlvii. lvi. lviii. lix.). They may be nearly all included in the four following groups:—

1. Catalogues of fundamental stars, published in 1872 and 1899; determinations of the velocity of light and of the constant of aberration (in this Professor Newcomb was

assisted by Professor Michelson); a discussion of Greenwich and Washington North Polar distances, and a determination of the constant of nutation from them; the constant of precession.

2. Discussions of Eclipses of the Moon and of Transits of *Mercury*, by Professor Newcomb; the discussion of the Greenwich Planetary Observations from 1762–1830, by Professor Safford.
3. Four papers on the Lunar Theory, two by Professor Newcomb; a transformation of Hansen's Theory compared with Delaunay's; the action of the planets on the Moon; and two by Dr. Hill on the lunar inequalities due to *Jupiter*, and lunar inequalities depending on the figure of the Earth.
4. A series of papers on the theory of the four inner planets by Professor Newcomb, forming the basis of his tables of their motions; the theory of *Jupiter* and *Saturn*, by Dr. Hill, and the tables of their motions based on it; the tables of *Uranus* and *Neptune* by Professor Newcomb, just published.

The enumeration of these papers, though incomplete, shows what a debt astronomy owes to the office of the American Ephemeris, and especially to Professor Newcomb and Dr. Hill.

F. W. D.

Variation of Latitude.

Some years ago the International Geodetic Association determined to carry out an elaborate scheme for the systematic observation of those variations of latitude to which Küstner first drew effective attention. It was considered that the Talcott method would give the most satisfactory results, and that method has accordingly been adopted. The same form of zenith telescope is to be used at all the stations, and the instruments have all been carefully tested at Potsdam. An exact programme for observation has also been arranged at the Bureau of the Association.

In order to avoid possible errors in the determination of the declinations of stars, and especially errors in the estimated proper motions, it was resolved that the same stars should be observed at all the stations. This involved the choice of places lying in the same parallel of latitude. After careful consideration of meteorological and geological data, Dr. Helmert fixed on the parallel of 39° 8′ N. as meeting all the requirements of the case.

The coordinates which express the motion of the pole would be determinable from observations taken at three stations, properly distributed as to longitude, but for the sake of greater precision six stations have been chosen. They are as follows:—

1. Torre di San Vittorio, Carloforte, in the island of San Pietro, lying close to the coast of the island of Sardinia. The observatory is in latitude 39° 8′ 12″, and in about 9° of east longitude.

2. A place nine kilometres north of Charjui, on the Amu Daria, in latitude 39° 8′ 10″, and east longitude 63½°.

3. Mizusawa, in the valley of Kitakami, Japan. The observatory is in latitude 39° 8′ 0″, and in east longitude about 141°.

4. Ukiah, California, in latitude 39° 8′ 0″, and west longitude about 123°.

5. The permanent observatory at Cincinnati, in latitude 39° 8′ 19″, and west longitude 84½°.

6. Gaithersburg, Maryland, a station on the Baltimore and Ohio Railroad, about 30 miles north-west of Washington. The latitude is 39° 8′ 10″, and west longitude 77°.

Invitations to cooperate will also be addressed to a number of other observatories.

A full account of the whole project is given in the *Comptes Rendus* of the Stuttgart Conference of 1898.

The work was begun in the autumn, and the first books of results have already been received at Potsdam from Carloforte, Charjui, and Cincinnati.

It is intended that the observations shall be continued for at least five years, and the results will be reduced at Potsdam.

G. H. D.

The Variations of Gravity at the Earth's Surface.

The International Geodetic Association has continued its systematic researches as to the local deflections of the vertical which are found to occur at various places. A large mass of material now awaits reduction at Potsdam, and it is expected that valuable results will be obtained as to the value of gravity and as to the Earth's figure.

Mr. Richard Threlfall and Mr. J. A. Pollock have devised and experimented with a new form of gravity balance.* In this instrument the authors have availed themselves of the remarkable elastic properties of quartz fibres. The construction and design of the instrument have involved a high degree of experimental skill, and the inventors are to be congratulated on the success which has attended their difficult enterprise. It seems probable that the comparative values of gravity at various places may now be obtained with a facility which was previously unattainable. The results may perhaps be not quite so accurate as those obtained by the best swinging of pendulums—although there is every reason to believe that the instrument will reap the benefit of further experience—but

* *Phil. Trans.* A. 1899, paper 245.

observations which, by the older methods, would require days or even weeks to accumulate will now be obtained in a few hours. The defect of the instrument resides in the fact that it depends on the life of an individual fibre of quartz; but the extraordinary toughness and vitality of Threlfall's fibres seem to show that this is a far less serious defect than might have been anticipated.
G. H. D.

The Measurements of Base Lines and Standards of Length.

Geodesists * continue to be more and more impressed by the advantages to be gained by M. Jäderin's method of measuring base lines. In this method the base is measured by unrolling a metallic tape of considerable length; and the gain in rapidity is so great that henceforth a number of subordinate bases will be laid out, where formerly reliance would have been placed solely on a single long base line for a large tract of country.

A new alloy, consisting of 36 per cent. of nickel and 64 per cent. of steel, has been found to possess the remarkable property that its coefficient of expansion only amounts to one-fiftieth of that of steel. This alloy is now being used for the construction of M. Jäderin's apparatus, and also for standards of length by the International Committee of Weights and Measures at Breteuil. Great advantages are anticipated from this remarkable discovery.
G. H. D.

The Astrographic Chart and Catalogue.

There has been no recent number of the bulletin of the Permanent Committee, and no information has been obtained as to the progress made during the year in the measurement of the photographs in other than the British observatories. The progress made at Greenwich, Oxford, the Cape, Sydney and Melbourne, is referred to in the reports to the Council from these observatories.

During the year two important publications have appeared, viz., the first volume of the Potsdam measures of Catalogue Plates, and the first issue of twenty enlargements of the Paris Chart Plates. It is most satisfactory to know that a beginning has at last been made in actual publication, and we believe that the work of English observatories will also soon be in print. The Paris charts are most beautifully done; each plate is enlarged to double the size (linear), or four times the area, as a heliogravure on a sheet of thick paper 22 in. × 17 in. The star images are shown as clear little dots in groups of three, each dot representing an exposure of thirty minutes, and the French are to be congratulated on the production of a piece of work of a kind in

* See *Comptes Rendus* of Internat. Geod. Conf. at Stuttgart, pp. 27 and 277.

which they always excel. But attention should be drawn to the dimensions that the whole chart will have on this scale. Twenty maps are over a third of an inch thick, and weigh 3½ lbs. The 22,000 maps of the whole chart will thus form a pile of paper 22 in. by 17 in. in section, and thirty feet high, weighing nearly two tons, and the total expense will be enormous. The cost of each sheet must be at least two shillings, which means £2,200 for the whole. It almost seems as though the smaller observatories would be crowded out after all. These sheets are of course being generously presented by the French Government; but if the chart is to be homogeneous, each observatory must present similar copies of its own zones in return, so that the sum above quoted must be spent on behalf of each observatory, in one form or another, for the maps alone.

Nor is the Potsdam volume much more reassuring in this respect. It contains the measures of fifty-seven plates; and if all the measures are printed on the same scale, there will be nearly 400 such volumes, occupying just four times the space of the Greenwich volumes for the last half-century. Are not the large observatories setting too high a standard? It seems more than probable that the smaller observatories must be content with a much more modest chart, such as Professor Pickering is continually constructing at Harvard; and as regards the publication of the measures, we must print them less like an *édition de luxe*, and more like the Greenwich results already in proof, which contain three or four times as many stars in a page as the Potsdam volume.

As regards the contents of this volume, in the Introduction Dr. Scheiner explains his method of measurement by means of two micrometer screws at right angles. He finds the work very laborious; two people, a measurer and an assistant, measure thirty stars per hour, and there is still some work for a computer before the printed rectangular coordinates are deduced. It is perhaps a fair estimate to take ten stars as the result of *one* person's labour per hour. Twenty years seems about the time which it is proposed to spend on the measurement alone at Potsdam. The plates are measured in one position only, and the results are thus affected with personal equations depending on magnitude to the extent of $0''\cdot6$ in some cases, though the accidental error of bisection has been certainly made small. These personalities have been determined, but apparently not applied. And Dr. Scheiner does not undertake to determine the plate-constants. He considers that this will be best done when the whole work is repeated in 100 years' time; his argument is that the labour of finding both sets of plate-constants together will be less than twice that of finding one set separately; and hence it would be false economy to do our half of the work now (*see* Introduction, p. xxxvi). The principles stated on pp. xxii and xl of the Introduction are not quite accurate; for instance, the plate is only corrected on p. xl for orientation, when refrac-

tion and aberration might just as readily have been included, as has been shown in numerous papers in the *Monthly Notices* during the last six years.

Dr. Scheiner has also partially discussed, both in this Introduction and in various papers in the *Astronomische Nachrichten*, the distribution of stars of different magnitudes, especially the point established by Kapteyn that the stars near the Milky Way are brighter photographically than visually; but he does not seem to have added anything to Kapteyn's discussion; indeed, as Kapteyn has himself pointed out, we shall not gain much by repeating the sort of work which he has done so fully and admirably in the *Cape Durchmusterung*; what is wanted is a special investigation such as is being undertaken at the Cape.

H. H. T.

Star Catalogues.

Catalogue of Fundamental Stars for the Epochs 1875 *and* 1900 *reduced to an Absolute System.*—This catalogue, undertaken by Professor Newcomb at the request of the Paris Conference of May 1896, is published in vol. viii. part ii. of the *Astronomical Papers*, prepared for the use of the American Ephemeris and Nautical Almanac. A list is given of 1597 stars, which occur in various ephemerides and fundamental catalogues, but insufficiency of material, especially in the case of southern stars, caused Professor Newcomb to reduce the number of stars in his catalogue to 1260. With the exception of the close polars, the stars are generally brighter than the sixth magnitude, and, as far as practicable, are distributed so that stars are given at intervals of from fifteen to twenty minutes for each zone of 10° near the equator, and at intervals of twenty to twenty-eight in higher zones.

The material at Professor Newcomb's disposal may be roughly summarised as Auwers' Bradley, the standard catalogues of Struve and Argelander, and various catalogues from 1830 to the present date of the Cape, Greenwich, Melbourne, Poulkova, and Washington Observatories. The difficulties in the deduction of a standard catalogue from these consist mainly in the determination of the systematic corrections, and to a certain extent in the weighting of the different catalogues, especially of Auwers' Bradley.

In the Right Ascensions Professor Newcomb adopts the equinox of "Newcomb's Catalogue of 1098 Clock and Zodiacal Stars." This differs from that adopted in the Fundamental Catalogue of the *A.G.C.* by $+^{s}\cdot019-^{s}\cdot100\,T$, where T is measured in decimals of a century from 1850. Terms of the form $a \cos \alpha + b \sin \alpha$ are applied to correct the periodic error in Right Ascension which crept into the adopted Right Ascensions used at Greenwich between 1830–1840, and which was reproduced by many observatories using Greenwich clock stars, and which has

only been eliminated by successive revisions. For the error in Right Ascension depending on declination, use has been made of Dr. Auwers' tables giving the correction to reduce the different standard catalogues to the system of the *A.G.C.* The differences for each catalogue between the correction for each zone of 5° and the mean correction applicable near the equator are treated as giving corrections of the form $x+y$ T to the system of the *A.G.C.*, for each zone of 5°. The deduced corrections are added to the mean correction $+^{s}{\cdot}019-^{s}{\cdot}100$ T applicable to the *A.G.C.* stars near the equator, and by applying these corrections to the *A.G.C.* to Auwers' Tables, the adopted corrections to the Right Ascension of the various catalogues are derived.

For the declinations Professor Boss's Catalogue has been used as furnishing a provisional or intermediary system. Professor Newcomb deduces $+0''{\cdot}09+0''{\cdot}38$ T (as before measuring T in decimals of a century from 1850) as a correction applicable to Boss's declination in the region of the equator. This correction is derived from observations of the planets, and is an expression of the fact that their orbits are in planes through the Sun's centre. This result, deduced from planetary observations, though supported to some extent by the observed declinations of stars at Greenwich and Poulkova, cannot be said to be well determined. It is, however, adopted as the best obtainable at the present time. Using the tables given by Professor Boss for reducing to his system, equatorial corrections to Newcomb's system are deduced; the correction is usually assumed to be zero at the pole, and to increase uniformly to the equator. In this way the corrections are obtained to Boss's system from the standard catalogues, modified so that the mean equatorial correction will be $+0''{\cdot}09+0''{\cdot}38$ T. These are solved as giving corrections of the form $x+y$ T to Boss's declinations for every 5° of declination, and the corrections of the standard catalogues to Newcomb's system derived.

No corrections having the Right Ascension as argument are applied to the declinations.

Tables are given of the systematic corrections to reduce the different catalogues to Professor Newcomb's system, and attention may be drawn to the remark that "the practice of applying systematic corrections has of late years been carried too far. Corrections for errors proceeding from causes not known with numerical exactness, but yet plausible, are unobjectionable. But correction for seemingly systematic errors, which cannot be plausibly traced to a known cause, should be regarded with suspicion."

Auwers' Bradley is considered at some length. It is found to require an equinox correction of $-0^{s}{\cdot}079$; no periodic correction to the Right Ascension is required, and a correction depending on the declination, whose maximum value is about $-0^{s}{\cdot}030$, is deduced.

For the declinations a correction depending on Right Ascension is deduced; but Professor Newcomb states that his work on the precessional constant showed that these corrections would have been better omitted. The correction depending on declination resolves itself into the question whether the corrections to the readings of Bradley's quadrant deduced by Dr. Auwers should be retained or not. Professor Newcomb uses them for stars north of 47° of dec., but not for stars south of this limit, pending the publication of Dr. Auwers' discussion.

The correction of Right Ascensions for personality depending on magnitude is discussed, but no corrections are applied except in the case of Pulkova, 1845 and 1865.

Professor Newcomb applies no corrections for variation of latitude, as these corrections can only be applied as corrections for each day in the reductions of observations, and not to a catalogue. In an appendix to the catalogue formulæ and data are given for the reduction of mean places and proper motions of stars from one epoch to another.

Cape General Catalogue of Stars for 1890.—This catalogue of 3007 stars is derived from observations made in the years 1885–1895. The stars observed are stars brighter than the fourth magnitude, fundamental stars, southern circumpolars, and stars required in the determination of latitude and longitude in connection with the geodetic survey. The Right Ascensions of the clock stars are derived from the *Berliner Jahrbuch*, and are those of Auwers' *Fundamental Catalog*.

The correction of the Right Ascensions for personality depending on magnitude is considered, and $-0^{s}\cdot014\,(M-4\cdot0)$ is given as a mean correction, which may be applied to the Right Ascensions of the catalogue. It is stated that in future fundamental work at the Cape the magnitude equation will be frequently determined for each observer, and the corresponding corrections applied to his observations.

For the declinations two results are given; in both a correction is applied for flexure derived from observations on the collimator; in the first or provisional values the refractions of the *Tabulæ Regiomontanæ* are used; in the final determination these are diminished in the ratio $1-\cdot00218$. But the most interesting feature of the reduction is that the correction for variation of latitude has been applied to the observations.

In an appendix to the catalogue are given comparisons of the catalogue with the Greenwich Five-year Catalogue and with the *Berliner Jahrbuch*, and also with the Cape Catalogues for 1880 and 1885, the Greenwich Ten-year Catalogue for 1880, the Radcliffe Catalogue for 1890, and the Melbourne Catalogue for 1880. The results of these comparisons are summarised in the Introduction in the form of tables of systematic differences between the Cape Catalogue and these various catalogues for each hour of Right Ascension and for each 5° of declination.

In a second appendix the meridian observations of *Sirius*,

Procyon, α and β *Centauri* from 1886 to 1895 are collected, reduced without proper motion to the epoch 1890·0.

In a third appendix the positions and proper motions of twenty-four southern circumpolar stars used for azimuth determination are determined from Cape observations and those at Melbourne and Cordoba. A Catalogue of the mean Right Ascensions and Declinations of these stars is given for every fifth year from 1875 to 1920.

Attention may be drawn to a remark of Dr. Gill's, "that the existing transit-circle is now exclusively employed in zone observations, and a new transit-circle is under construction for future fundamental work. The present Catalogue is thus probably the last of its class that will emanate from the Cape Observatory as the result of work with a non-reversible instrument."

The Catalogue of the Astronomische Gesellschaft.—Leipzig Zones.—Zone $+5°$ to $+10°$ has been published this year, and Zones 10° to 15° are in the press. The former contains 11,875 stars, and the latter will contain 9547 stars. The northern half of the *Gesellschaft* Catalogue from $-2°$ to $+80°$ decl. is thus nearing completion; the zones still unpublished are those of Lund and Leiden, extending from 30° to 40° N. decl., and the Dorpat Zone from 70° to 75°. The Leipzig Zone from $4°{\cdot}42'$ to $10°{\cdot}0'$ N. decl. was observed with a Pistor and Martin's circle by Drs. Bruns and Peter in the years 1868–72 and 1883–93. The majority of the stars are observed twice, but a considerable proportion of the stars are observed oftener. A comparison with the Greenwich new Ten-year Catalogue, 1890, shows a difference of ${}^{s}{\cdot}05$ in the Right Ascensions and $-0''{\cdot}3$ in the Declinations. There appears to be no systematic difference either in R.A. or Decl., depending on the Right Ascension. The mean discordance between the two catalogues from comparisons of the 160 stars common to them is $\pm{}^{s}{\cdot}039$ in R.A., and $\pm 0''{\cdot}49$ in Decl.

F. W. D.

Double Stars.

As in previous reports the work is arranged under the two heads, "Observation" and "Calculation."

Observation.—*Mem. R.A.S. Vol. liii.* contains measures of 161 pairs made with an 8-inch Cooke refractor in the years 1893–96 by Mr. W. Coleman; also of 98 pairs made by Mr. Maw with an 8-inch formerly used by Dawes. This set brings Mr. Maw's measures up to 1808.

Monthly Notices R.A.S. 1899 *April.*—Measures of 73 pairs made at Shanghai by Mr. J. L. Scott with a 5-inch refractor; also the mean results of micrometric measures of 420 pairs made with the 28-inch Greenwich refractor during the years 1896, 1897, 1898.

Astronomical Journal.—No. 429 contains measures of 83 close pairs made at Lick by R. G. Aitken. (This set was unfortunately omitted in the last Report.) No. 462.—Measures of *Procyon* by E. E. Barnard. No. 468.—Measures of *ζ Herculis* by T. Lewis (1894–99).

Astronomische Nachrichten.—No. 3537 contains W. Schur's measures of 70 *Ophiuchi* in 1898, No. 3558 a catalogue of 132 new doubles (Hough 491–622), and a good set of measures of 255 other pairs by G. W. Hough with the 18½-inch Dearborn refractor. No. 3563.—M. Solă gives his third series of measures (50 pairs). Nos. 3584–5 contain a fine series of measures of some 400 pairs by R. G. Aitken with the 36-inch Lick refractor (includes measures of *Sirius* and *Procyon*); the same number contains measures of *Sirius* by Professor W. Hussey.

Astronomical Society of the Pacific.—No. 66.—Professor Aitken has some notes and measures of *β Orionis*, *ε Hydræ*, 48 *Cassiopeiæ*, *Procyon*, and H 529. In the same number is a new close pair by Perrine. No. 68 contains measures of *Sirius* by R. G. Aitken, and three new close pairs. No. 69.—Five new pairs by R. G. Aitken.

Popular Astronomy.—No. 63.—Professor W. Hussey gives four new pairs.

Calculation.—*Ast. Nach.* 3588.—Orbit of *Sirius* by H. Zwiers, who, using observations down to 1899·3, obtains a period of 48·84 years. No. 3546.—Note on systematic error in the Poulkova double star measures by V. Ehrenfeucht. No. 3593.—Parallax of Σ 1516 by Ö. Bergstrand.

Astron. Journal.—No. 460.—Orbit of *ζ Herculis* by Eric Doolittle. Period 35·55 years. There is a further note by the same author in No. 466, where a comparison is made between observed and computed places. In 461 Professor F. R. Moulton has a paper on "The Limits of Temporary Stability of Satellite Motion," with a special application to the system 70 *Ophiuchi*.

Popular Astronomy.—No. 61.—Note on *β* 107 by S. W. Burnham. No. 66.—Rough orbit of Dembowski 15 by Mr. Evans.

The Observatory.—No. 277.—Motion of Σ 1263 by T. Lewis. No. 285.—Parallax of Σ 1516. No. 286.—Note by T. Lewis on the system 7 *Tauri* (Σ 412). The close pair is binary, the third star apparently being unconnected with the system.

Reference Catalogue of Southern Double Stars.—This catalogue, by Mr. R. T. A. Innes, is published as "Annals of the Royal Observatory, Cape of Good Hope," vol. ii. part ii., and is a most valuable descriptive catalogue containing over 2000 stars arranged in order of R.A., and each star is accompanied by a sufficient number of measures (where possible) to enable an observer to see at once those pairs which want measuring, and which lie within the limits of his instrumental means. It also contains a most complete list of works and papers on double stars. Such a catalogue as this had become an urgent necessity. T. L.

Longitude Determination.

The only recent publication which comes under this heading is that of the details of the arc Leyden—Greenwich, measured in the year 1880 by the brothers H. G. and E. F. van de Sande Bakhuyzen, which appear in volume vii. of the *Leyden Annals.* The provisional result was given in the report of the International Geodetic Association for 1883, and the definitive result in a subsequent report of the same body, so that there is not any information which is actually new, but it may be of interest to note some details.

At Leyden the meridian circle of the Observatory was used for determination of time. At Greenwich a transit *à lunette brisée* of aperture 67·8 mm. and focal length 861 mm., on an iron stand, was mounted in the south ground at Greenwich, on the same stone base that Professor Oppolzer had used in 1876. This instrument was easily reversed in its bearings, and it was so reversed several times during an evening's work. The meridian circle at Leyden was reversed once only during each of the periods into which the work was divided.

The observers interchanged stations once. This interchange is sufficient to determine, and hence eliminate the relative personal equation of the observers ; but as there may be a personality due to the instruments used, some months after the Greenwich observations were completed the smaller instrument was set up at Leyden, and the observers repeated the operations exactly, so as to determine the small difference of longitude between the instruments which was known by direct measurement. The relative personal equation deduced from these observations was H.B.—E.B. $= -0^{s}\cdot293$. From the previous observations it had been $-0^{s}\cdot258$. Comparison of the determined longitude with the linear distance showed a difference of clock-error due to the instruments of $0^{s}\cdot012$ and some account of this being taken in the discussion of results, the difference of longitude arrived at between the meridians of the Greenwich transit circle and that of Leyden is $17^{m}\ 56^{s}\cdot10$.

The most unsatisfactory detail of the operations appears to be the telegraph signals. Although care was taken to equalise the strength of currents in sending and receiving signals, it is possible that the times of transmission, which were sometimes large, were not always the same in opposite directions, but Professor Bakhuyzen thinks that the error of the result due to this cause cannot be more than $^{s}\cdot01$ or $^{s}\cdot02$.

It is worth remarking that a few years later the difference of longitude between Leyden and Paris was determined telegraphically, with result $8^{m}\ 35^{s}\cdot213$; the combination of these results gives for the longitude of Paris $9^{m}\ 20^{s}\cdot89$ East of Greenwich.

H. P. H.

Stellar Spectroscopy in 1899.

Spectrum of Nebulæ.—From a photograph obtained with an exposure of 7½ hours, at Potsdam, of the spectrum of the *Andromeda* nebula Professor Scheiner (*Astroph. Journ.* ix. 149) infers that the nucleus is composed of stars that belong in the main to the solar class. Professor Scheiner calls attention, in a suggestive manner, to a point which deserves systematic investigation, viz. the difference between the spectra of ring nebulæ and spiral nebulæ.

Professor Keeler has made reference, in a paper on the ring nebula in *Lyra* (*Astroph. Journ.* x. 200), to the preparation of apparatus suitable for this and allied researches, and results of great importance may be expected.

New Star in Sagittarius.—A new star was discovered by Mrs. Fleming, of the Harvard College Observatory, by the peculiarities of its spectrum as photographed in March 1898. It was then a star of the fifth magnitude, but at the time of its detection—viz. in March 1899—it was found to be of the tenth magnitude. Eighty-seven plates of the region were examined, and the search only showed that it was too faint to be photographed between the years 1888 and 1897. Professor E. C. Pickering (*A. N.* 149, 57) states that the *Nova* is invisible on the last plate of the region taken in 1897, though stars of the fifteenth magnitude are to be seen on the plate. The star probably appeared either at the end of 1897 or early in 1898. It is of great interest, both on account of its having at its first appearance peculiarities in its spectrum—which Professor Pickering regards as possibly affording a general method of distinguishing between a *Nova* and a variable—and also on account of the fact that it appears to have passed through changes similar to those presented by *Nova Cygni*, *Nova Aurigæ*, and *Nova Normæ*. Furthermore it makes its appearance near the central line of the Milky Way, a fact which must have significance when it is considered, as Professor Pickering points out, that fourteen out of the fifteen new stars which have been observed during the last 400 years have been situated close to that line.

Professor Campbell's visual observations (*Astroph. Journ.* ix. 308) in April 1899 show that the spectrum was at that time similar to that of *Nova Aurigæ* in August 1892, and the resemblance to the planetary nebular spectrum is no less striking.

Phenomena of Spectrum of New Stars.—A striking feature in the spectrum of *Nova Aurigæ* (1892) at its first outburst was the occurrence of pairs of lines, a bright line and a dark line side by side, the dark line being more refrangible. The same feature was visible in *Nova Cygni* (1876), in *Nova Normæ* (1893), and in *Nova Sagittarii* (1898), and it is now regarded as a peculiarity of new stars. Belopolsky also announces (*Ast. Nach.* 151, 37,

and *Astroph. Journ.* x. 319) that the same feature is still seen in Janson's *Nova* of 1600, now known as *P Cygni*; and it is connected not only with the helium and hydrogen lines, as has long been recognised, but also with lines which seem to be attributable to nitrogen. In all of these cases the bright lines are displaced towards the red. The researches of Humphreys and Mohler show that such displacement is produced by increase of pressure in the incandescent vapour. Herr Wilsing, in trying to extend the work of these experimenters, has investigated the spectra of spark discharges below the surface of liquids (*Sitz. ber. Berlin. Akad.* 1899 May, and *Astroph. Journ.* x. 113). He finds in many of the spectra examined there are pairs of lines, consisting of a bright and a dark line, the bright line being displaced towards the red, whilst the displacement of the dark component is seldom appreciable. In the case of copper and cadmium the shifts of the bright lines amount to 4 or 5 tenth-metres, and in the zinc the bright line 4722 was shifted through 14 tenth-metres. In new stars displacements of the bright line through 8 or 10 tenth-metres are observed, and this is accompanied by a shift of the dark lines towards the violet. Herr Wilsing finds little evidence of the shifting of dark lines in the case of metallic spectra, but has succeeded in getting striking results with hydrogen (*Sitz. ber. Berlin. Akad.* 1899 July, and *Astroph. Journ.* x. 269). Much remains to be done in the subject, but it is clear that Herr Wilsing has entered upon an important research, not only in the study of the broadening, both symmetrical and unsymmetrical, of metallic lines, but also in particular with reference to the spectroscopic behaviour of hydrogen. He deals with the application of his observations to the case of new stars, in *Ast. Nach.* 151, 33, No. 3603.

Chemistry of Stars.—Mr. McClean's identification of oxygen in helium stars, *e.g.* *β Crucis*, has been confirmed by Dr. Gill at the Cape of Good Hope by careful comparison of wave-lengths of the stellar lines with oxygen and other comparison spectra (*Proc. R.S.* lxv. 196, and *Astroph. Journ.* x. 272). This is, we believe, the first piece of research carried out with the splendid spectroscopic installation presented by Mr. McClean to the Cape Observatory.

Sir William Huggins (*Ast. Nach.* 149, 231) moreover points out that about 10 lines attributed by Neovius to oxygen appear in the spectra of *β Orionis* and *β Lyræ*. In a later note he calls attention to the fact that in *β* and *γ Orionis* there appears a strong line coinciding with a strong nitrogen line, and in the latter star there are several other nitrogen lines. Herr Belopolsky (*Ast. Nach.* 151, 37) states that nitrogen lines appear in *P Cygni*. Sir Norman Lockyer in several papers published during the year refers to results obtained with the 42-inch Spottiswoode induction coil in a comparison of the spectra of the arc and an intense spark. He has given special attention to lines which are intensified or enhanced in the spark spectra, and

summarises results by distinguishing between lines of proto-metallic origin or enhanced lines, and lines of metallic origin. He identifies most of the lines in *α Cygni* with proto-metallic lines (*Proc. R.S.* lxiv. 320, *Nat.* lix. 342). He studies the spectrum of silicium (*Proc. R.S.* lxv. 449, *Nat.* lxi. 262), and identifies several strong stellar lines—*e.g.* in *β*, *γ*, and *ζ Orionis*—with that element. Lines referred to by Dr. Gill as of unknown origin, and of great strength in the spectra of *β Crucis* and *β* and *ε Canis Majoris* at λ 4552·79, 4567·09, and 4574·68, are probably identical with the group C attributed by Lockyer to silicium. In a paper (*Proc. R.S.* lxv. 452, *Nat.* lxi. 263) Lockyer gives a "Preliminary Table of Wave-lengths of Enhanced Lines." Mr. J. Lunt has a paper (*Proc. R.S.* lxvi. 44) on Silicium lines in stellar spectra.

Classification of Stellar Spectra.—In the *Publications of the Potsdam Observatory*, vol. xii. part 1, Professor Vogel and Dr. Wilsing give the results of the examination of photographs of spectra of 528 stars. Guided by the Draper Catalogue they studied stars of the First Type not fainter than fifth magnitude between the Pole and −5° declination. The spectra, which were 10 mm. long between λλ 370 and 448, and 0·2 mm. wide, were taken with exposures of 12 to 15 minutes with a single-prism spectroscope attached to the 13-inch photographic refractor. The work consists of (i) a catalogue of stars, following the introductory note, and description of the system of classification adopted by Professor Vogel; (ii) a section dealing with measurements of photographs relating to 130 stars (mainly helium stars) by Professor Vogel; and (iii) a comparison with results recorded in the Draper Catalogue and in "Spectra of Bright Stars" discussed by Miss Maury under Professor Pickering's direction (*Annals Harv. Coll. Obs.* xxviii. 1).

Professor Hale (*Astroph. Journ.* x. 87), in a note dealing with spectra of stars of Secchi's Fourth Type, shows that an important piece of work has been inaugurated at the Yerkes Observatory in a branch of stellar spectroscopy that gives promise of being as fruitful as it is difficult. Instrumental power is being pushed forward in a bold way, and portions of the spectrum of *Schjellerup* and other stars of even seventh and eighth magnitudes have been photographed with slit spectroscopes. M. Dunér (*Astroph. Journ.* ix. 119) gives an account of visual observations of spectra of stars of Secchi's Fourth Type (Vogel's III. *b*). Both he and Professor Hale and Mr. Ellerman seem to detect bright lines in the spectra examined, and evidence is rapidly being accumulated in order to settle this difficult question.

Reference to the three researches just named makes it clear that classification is entering on a new phase, in which observers confine themselves to careful study of a single type rather than range over the wide field of general classification.

In a wider field of suggestiveness Sir Norman Lockyer deals with a new set of observations obtained with the powerful induction coil already referred to, and applies them to explanation

of stellar phenomena, always presenting them, however, in terms of his particular modes of classification. In his papers "On the Order of Appearance of Chemical Substances at Different Stellar Temperatures" (*Proc. R.S.* lxiv. 396, and *Ast. Nach.* 149, 225) and "On the Chemical Classification of the Stars" (*Proc. R.S.* lxv. 186) he follows up lines of work already indicated in his paper "On the Chemistry of the Hottest Stars." The difficulty in this kind of work lies clearly in the choice of an indisputable scale or order of temperatures in stars.

Velocity in the Line of Sight.—Professor Vogel (*Sitz. ber. Berlin. Akad.* 1898 Nov., and *Astroph. Journ.* ix. 1) has investigated the spectrum of *α Aquilæ*, and finds no evidence of orbital motion such as was announced by M. Deslandres (*C.R.* cxxi.). Vogel concludes that the lines in this star are broadened in consequence of the rotation of the star.

Professor Campbell (*Astroph. Journ.* ix. 86) finds that *ζ Geminorum*, a well-known variable, has a variable velocity in the line of sight; and Herr Belopolsky (*Ast. Nach.* 149, 239) corroborates the observation, giving results of measurement of 15 photographs showing that the period of variation of velocity coincides with that of the light changes. Herr Belopolsky (*Mem. Soc. Spettr. Ital.* xxviii.) has continued his observations of the variable velocity of the fainter component of *Castor*, and finds that the line of apsides has a rapid movement, the period of revolution being 4 years 40 days. The period of this star in its orbit is 2·93 days.

Mr. W. H. Wright (*Astroph. Journ.* ix. 59) discusses the orbit of *η Aquilæ*. Herr Belopolsky had announced variability in this star's velocity in 1895 (see *Astroph. Journ.* vi. 392).

Professor Campbell (*Astroph. Journ.* ix. 31) discusses some remarkable observations of *ο Ceti*, which have led him and Mr. Wright to make careful determinations of the wave-length of the hydrogen line H_δ. The wave-length is found to be 4101·87, as compared with Rowland's value 4102·00 [cf. *Astroph. Journ.* ix. 50 (Wright) and ix. 211 (Jewell)]. Professor Campbell (*Astroph. Journ.* ix. 310) states that *ι Pegasi* and *θ Draconis* have variable velocities, and (*Astroph. Journ.* x. 178) adds *ε Libræ*, *h Draconis*, *λ Andromedæ*, *ε Ursa Majoris*, and *ω Draconis* to the list of stars with variable velocity. He announces the discovery of the binary character of *Capella* (*ibid.* x. 177), a discovery independently made by Mr. Newall (*Monthly Notices*, lx. 2; see also *Observatory*, 1900, pp. 92, 93). Professor Campbell announces that *Polaris* is a multiple system (*Astroph. Journ.* x. 180), and Professor E. B. Frost also gives observations of this star (*ibid.* x. 184). Professor Campbell adds yet two more stars, *β Capricorni* and *υ Sagittarii*, to the list of stars with variable velocity (*ibid.* x. 241).

Reduction of Spectrum Measurements.—Astronomers have shown their appreciation of Dr. J. Hartmann's relation connecting wave-lengths and micrometric measurements by adopting it, one may almost say, universally. Dr. Hartmann finds (*Potsdam*

Observations, XII. ii.) that the best relation is of the form $\lambda-\lambda_0=C/(R_0-R)^a$, where λ_0 R_0 C are constants to be determined by the use of standard reference lines, and a is an index of value $\frac{6}{5}$. He points out that the approximation got by putting $a=1$ is very satisfactory. This relation had been first given by Cornu in 1881 (cp. Salet's *Spectroscopie*, Paris, 1883, p. 75), but, strange to say, it had fallen into disuse.

Dr. Gill (*Proc. R.S.* lxv. 196, and *Astroph. Journ.* x. 276) gives yet another relation of the form, $\log(\lambda-\lambda_0)=(R_0-R)\times$ const.

Attention may be called to the convenient tables published by Dr. Schlesinger (*Astroph. Journ.* x. 1) under the title "Line of Sight Constants for the Principal Stars." Latitude and longitude are given for each of 371 bright stars visible from northern observatories, for the epoch 1900, together with a table of precessions in longitudes up to 1930. The value 8″·80 is adopted for the solar parallax.

H. F. N.

Sir William and Lady Huggins's Atlas of Representative Spectra.

In the striking volume which has just appeared, published in such tasteful form as to recall some ancient volume rather than a modern scientific work, Sir William and Lady Huggins set forth an account of pioneering research in astrophysics. The volume contains a remarkable series of plates reproduced from photographs of stellar spectra between the wave-lengths 4870 and 3300. This series has doubtless determined the title of the volume, but the plates are accompanied by 165 pages of text, which contain much new and important matter, dealing, as the title-page indicates, with the "evolutional order of the stars and the interpretation of their spectra."

The Atlas forms Vol. I. of the Publications of Sir William Huggins's Observatory. The first chapter accordingly contains the history of the Observatory, dating from the year 1856, when the chief instrument was a five-inch equatorial by Dollond. The earlier work is left to speak for itself, as it appears in the titles of papers on the work done in the Observatory, and Sir William Huggins has confined himself entirely to the history of the development of spectroscopic observation, in which he has taken so leading a part. A list of 81 papers forms Chapter II., with no further commentary than appears in an attractive Initial, drawn, like many others in the volume, by Lady Huggins.

Then follows a description both of the methods of taking the photographs of stellar spectra and of the spectroscopes in use in the Observatory, including also a new and ingenious device for automatically giving the necessary breadth to the photographic stellar spectra during the exposures (p. 61).

The discussion of the evolutional order of stars is contained in Chapter VI. (pp. 65–106), and forms perhaps the most

important part of the volume. Following up the lines indicated in 1879 in his paper "On the Photographic Spectra of Stars," and emphasised in his Presidential Address to the British Association in 1891, Sir William Huggins now reviews more recent evidence. In his earlier work he chose as a true natural criterion, clearly indicating successive changes of density and temperature, the gradual increase in strength of the calcium lines, together with other changes in the spectra. He arrived thereby at an order or sequence of certain typical stellar spectra, and regarded it as possibly indicating the successive stages in the life changes through which a star passes. This scheme was in general agreement with that independently arrived at by Vogel in 1874.

Sir William Huggins (accepting Lane's work, which shows that a gaseous mass rises in temperature if, whilst it is compressed under gravitation, it remains subject to the laws of a purely gaseous body) sets forth general considerations which weigh with him in arriving at the conclusion that the Sun and *Capella* are types of the stars at the maximum temperature. He then replaces general considerations by a definite piece of evidence of the greatest importance, viz. that photographs of the ultra-violet region of various stellar spectra taken with special precautions, make it clear that the ultra-violet photospheric radiation, where it is undimmed by special absorption in the stellar atmosphere, is relatively to the blue more intense in Solar stars than in Sirian.

The evidence is at variance with that of other observers, notably Lockyer's; and the clear statement of a definite issue is a step of great value. The question is one that can be settled only by extreme care and with special instrumental appliances. Sir W. Huggins has got a range of spectrum from $\lambda 4870$ to $\lambda 3300$, and—most important of all—he has used a mirror for collecting the light which is passed into the spectroscope, and so he avoids all the difficulties introduced by chromatic observation in refractors.

Chapter VII. consists of a description of Historical Spectra which are reproduced in Plate 2. In this chapter also there is new matter and promise of more, for we have in it some of the results of recent investigations with respect to the *Andromeda* nebula, and learn that a new instrument has for some time been mounted in the Observatory for special work of this kind. The Atlas proper is discussed in Chapter VIII. (pp. 131–165), which is headed Preliminary Discussion of the Spectra on the Plates. The authors draw attention to the significance of the first word of the title, and add that their main object is to place in the hands of those interested in the subject representative spectra of the principal classes of star through a long range of wave-length. The text contains, among other important matters, a discussion of recent photographs of the spectrum of the *Orion* nebula; and the authors infer from the new evidence that the stars of

the Trapezium are physically and evolutionally connected with the great nebula, as was suggested in 1889. The connection is of great import, and the authors are led in great measure by consideration of it to choose the Helium star *Bellatrix* as representative of the earliest stage in evolution (leaving out of account the Wolf Rayet stars).

Though Sir William Huggins does not definitely state it, it would appear that the provisional order of evolution now adopted by him may be indicated as follows :—

Order adopted in 1899.	Order adopted in 1879.
Bellatrix.	*Sirius—Vega.*
Rigel.	*α Ursæ Majoris.*
α Cygni (distinct individuality).	*α Virginis.*
Regulus.	*α Aquilæ.*
Vega.	*Rigel.*
Sirius.	*α Cygni.*
Castor (fainter star).	—
Altair.	—
Procyon.	*Capella*—The Sun.
γ Cygni.	*Arcturus.*
Capella [highest temperature].	*Aldebaran.*
Arcturus.	*Betelgeuze.*
Betelgeuze.	

For convenience the earlier order is also given. Each list begins with stars in an early diffuse state.

Dr. Isaac Roberts's Photographs of Stars, Star-clusters and Nebulæ. Volume II.

Dr. Roberts has recently published a second volume of photographs of stars, star-clusters and nebulæ. The first volume appeared in 1893. The present collection consists of 72 photographs on 28 plates, together with descriptive text and two charts illustrating measurements of stars and bright points in certain spiral nebulæ. The reproductions are admirably carried out, and astronomers are thus, thanks to the public spirit of Dr. Roberts, put in possession of a very valuable collection of records printed in permanent ink. Dr. Roberts does well to call attention once more to the perishable nature of glass negatives; he gives numerical details of the decay of some negatives in his possession. On one plate he counted 403 stars shortly after the plate was obtained; nine and a quarter years later 131 of these stars had disappeared by fading, and similarly with other plates.

In more than one place in the volume Dr. Roberts refers to a very remarkable result. It would appear that an exposure of ninety minutes secures as many stars as an exposure of ten or

twelve hours on plates of like sensitiveness. The only effect of longer exposure is to give greater density of images. Dr. Roberts does not refer to the suggestion that has been made that this is a sign that light must be of a definite intensity in order to affect a photographic plate enough to give a developable image.

The photographs are arranged in the following order :—

Plates 2–9. Photographs of rich fields of stars and of clusters.

Plates 10–18. Photographs of spiral nebulæ.

And following these are photographs of nebulæ, of circular, annular, and irregular forms ; and, lastly, nebulæ of large areas of cloud-like matter. In a volume that contains so many beautiful plates it is difficult to single out special instances. It is, however, perhaps allowable to call special attention to

Plate 5. Chart of stars in *Cygnus* (cf. vol. i. p. 111),

Plate 21. Nebula H. V. 14 *Cygni*,

Plate 22. N.G.C. 1499 *Persei*,

Plate 27. N.G.C. 2237–9 *Monocerotis*.

Dr. Roberts has measured the positions of 81 stars and condensations in and around the spiral nebula M. 51 relatively to the nucleus as photographed in 1898, and gives the results in a table. In the case of 14 of these he is able to make comparison with Lord Rosse's measures made in 1872–74, and finds evidence that movements have taken place in the intervening 26 years. (The interval is by a slip described in the text as 47 years.) Dr. Roberts warns us that the evidence must be accepted with caution. The movements are in some cases so large that we may hope that Dr. Roberts himself will be able to check them entirely from his own observations in the course of the next few years.

Papers read before the Society from March 1899 to January 1900.

1899.

Mar. 10. Observations of *Eros* (1898 DQ.), made with the 30-inch reflector of the Thompson equatorial of the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on Dr. Rambaut's remarks in the *Monthly Notices* for November 1898. David Gill.

Occultations observed at the Royal Observatory, Cape of Good Hope, during the lunar eclipse of 1898 December 27. Communicated by H.M. Astronomer.

Nebulæ observed at the Royal Observatory, Cape of Good Hope, during the year 1898. Communicated by H.M. Astronomer.

On the use of the electric light for the artificial star of a Zöllner photometer. W. de Sitter.

The Radiant Point of the April meteors (*Lyrids*). W. F. Denning.

Theory of the motion of the Moon; containing a new calculation of the expressions for the coordinates of the Moon in terms of the time. E. W. Brown.

General Catalogue of the Radiant Points of meteoric showers, and of fireballs and shooting stars observed at more than one station. W. F. Denning.

Observations of Hind's variable Nebula in *Taurus*. E. E. Barnard.

Determination of the diameter and compression of the planet *Mars* from observations with the Repsold heliometer of the Royal Observatory, Göttingen. (Second communication.) W. Schur.

Periodic variation in the colours of the equatorial belts of *Jupiter*. A. S. Williams.

Double Star observations, 1895–98. W. H. Maw.

Note on the diurnal variations of the nadir and level of the transit circle at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

The Greenwich meridian observations of *Polaris* 1836–93, with reference to personality, the value of the constant of aberration, and the star's parallax. W. G. Thack

\pr. 14. Double Star observations, 1897–98. J. L. Scott.

Photographs of the Radiant of the *Leonid* meteors, and attempts to photograph the meteor stream. Isaac Roberts.

Further observations of comet Coddington (*c* 1898). John Tebbutt.

Results of micrometer measures of double stars made with the 28-inch refractor at the Royal Observatory, Greenwich, in the years 1896, 1897, and 1898. Communicated by the Astronomer Royal.

On the errors of star photographs due to optical distortion of the object glass with which the photograph is taken. H. H. Turner.

Observations of planet (433) *Eros*, and of comet Tuttle, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Observations of planet *Eros* from photographs taken with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Iay 12. Observations of Tuttle's comet (*b* 1899) made with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Observations of Swift's comet, 1899, made at Grahamstown, South Africa. L. A. Eddie.

Observations of *Mars* made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition of 1898–99. Joseph Gledhill.

Longitude from Moon culminations. D. A. Pio.

Remarks on the paper by Professor W. Schur, together with determination of the diameter and polar compression of the planet *Mars* from observations with the Repsold heliometer of the Remeis Observatory, Bamberg, and with the Breslau heliometer at the Observatory, Strassburg, in 1879. Ernst Hartwig.

On the errors of star photographs due to optical distortion of the object glass with which the photograph is taken. (Second paper.) H. H. Turner.

Note on the spectra of γ *Cassiopeiæ* and *o Ceti*. Rev. W. Sidgreaves.

Observations of the satellite of *Neptune* from photographs taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the constitution of *Saturn's* crape ring. E. M. Antoniadi.

une 9. On the curvature of star trails on a photographic plate as a means of investigating optical distortion. H. H. Turner.

On the formulæ of reduction to the meridian of the observed zenith distances of stars. A. E. Young.

A further investigation concerning the position error affecting eye-estimates of star magnitudes. A. W. Roberts.

Equatorial comparisons of *Jupiter*, *Uranus*, and *Neptune* with certain stars in Newcomb's Standard Catalogue. John Tebbutt.

Note on the nebula N.G.C. 6535. W. H. Robinson.

Note on the construction and use of Réseaux. A. R. Hinks.

Ephemerides of two situations in the *Leonid* stream. G. J. Stoney and A. M. W. Downing.

Observations of comet *a* 1899 (Swift) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Ephemeris for physical observations of the Moon for the second half of 1899. A. C. D. Crommelin.

Small nebulæ discovered with the Crossley reflector of the Lick Observatory. J. E. Keeler.

Nov. 10. Note on the motion of *Jupiter's* red spot. C. Flammarion.

Comparisons of the geocentric places of *Mercury*, *Venus*, *Mars*, *Jupiter* and *Saturn*, calculated from the tables of the American Ephemeris Office with the places calculated from Le Verrier's tables for the year 1901. A. M. W. Downing.

The magnitude of η *Argûs*, 1899. R. T. A. Innes.

Observations of *Mars* during the apparition of 1898–99. Rev. T. E. R. Phillips.

On the optical distortion of a doublet lens. Capt. E. H. Hills.

List No. 12 of nebulæ discovered at Lowe Observatory, Echo Mountain, California, for 1900-0. Lewis Swift.

Further notes on *Saturn's* crape ring. E. M. Antoniadi.

Note on the geographical position of the University Observatory, Oxford. A. J. Walker.

Observations of *Jupiter* in 1899. W. F. Denning.

Early history of the great red spot on *Jupiter*. W. F. Denning.

Observations of *Jupiter* and his satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition of 1898–99. Joseph Gledhill.

Tempel's comet, 1873 II. (*c* 1899), observed at Grahamstown, Cape of Good Hope. L. A. Eddie.

Ephemeris for physical observations of the Moon for the first half of 1900. A. C. D. Crommelin.

Observations of nebulæ made at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

The Bruce micrometer of the Chamberlin Observatory. H. A. Howe.

On the probable motion of the annular nebula in *Lyra* (M. 57), and the peculiarities in the focus for the planetary nebulæ and their nuclei. E. E. Barnard.

The exterior nebulosities of the *Pleiades*, with a drawing from the different photographs; and on the appearance of the involved nebulosities of the cluster with the 40-inch refractor. E. E. Barnard.

On the diameters of *Ceres* and *Vesta*. E. E. Barnard.

The theory of the Figure of the Earth carried to the second order of small quantities. G. H. Darwin.

On the distribution of stars photographed at the University Observatory, Oxford, for the Astrographic Catalogue for zones $+25°$ to $+29°$. F. A. Bellamy.

On the variation of personal equation with stellar magnitude in observations made at Cambridge, Berlin, and Greenwich; as deduced from measures of photographic plates taken at Oxford. H. H. Turner.

Comparison of the diameters of the images of stars on the Greenwich astrographic plates with the magnitudes given in the *Bonn Durchmusterung*. F. W. Dyson and H. P. Hollis.

Preliminary note on the spectrum of *α Aurigæ*. H. F. Newall.

Dec. 8. Ephemeris for physical observations of *Jupiter*, 1899–1900. A. C. D. Crommelin.

Note on the values of the coefficients of the terms of the third order in the new Lunar theory. E. W. Brown.

Observations of the *Leonids* of 1899 made at the University Observatory, Oxford. H. H. Turner.

On the proper motions of Berlin B, Nos. 5072 and 5073. F. A. Bellamy.

New nebulæ discovered photographically with the Crossley reflector of the Lick Observatory. J. E. Keeler.

Observations of the *Leonids* of 1899 made at Durham Observatory. Communicated by R. A. Sampson.

On the relation between magnetic disturbance and the period of solar spot frequency. William Ellis.

The extra-equatorial currents of *Jupiter* in 1899. Rev. T. E. R. Phillips.

Mean areas and heliographic latitudes of Sun-spots in the year 1898, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of the *Leonids* of 1899 November 14 and 15, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Results of observations of the *Leonid* meteors of 1899, as seen from the Royal Observatory, Edinburgh. George Clark.

Observations of the *Leonid* meteors of 1899 made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

1900.

Jan. 12. Note on the variable star η *Argûs.* Col. E. E. Markwick.

Observations of meteors, 1899 November, made at the Royal Alfred Observatory, Mauritius. Communicated by T. F. Claxton.

Note on the physical constitution of the lunar surface. George Forbes.

The determination of selenographic positions and the measurement of lunar photographs. S. A. Saunder.

Observations of the lunar eclipse 1899 December 16 at the Liverpool Observatory. W. E. Plummer.

Some suggestions for the explicit use of direction cosines or rectangular coordinates in astronomical computations. H. H. Turner.

On the unpublished observations made with the transit instrument and quadrants at the Radcliffe Observatory, Oxford, between the years 1774 and 1838. A. A. Rambaut.

Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, in the year 1899. Communicated by the Astronomer Royal.

Micrometric measures of β 883 with the 28-inch refractor at the Royal Observatory, Greenwich, in 1899. Communicated by the Astronomer Royal.

Ephemeris for physical observations of *Mars*, 1900–1901. A. C. D. Crommelin.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

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Oxford, Radcliffe Observatory.
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Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.

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Batavia, Magnetical and Meteorological Observatory.
Batavia, Natural History Society of Netherlands-India.
Belgium, Royal Observatory.
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Berlin, German Transit of Venus Commission.
Berlin, Institute of Computation of the Royal Observatory.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
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Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Calcutta, Asiatic Society of Bengal.
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Canada, Geological Survey.
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Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania, Royal Observatory.
Chicago Academy of Sciences.
Cincinnati Observatory.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine Meteorological Office.
Cracow, Academy of Sciences.
Dijon, Academy of Sciences.
Geneva, Society of Physics and Natural History.
Georgetown College Observatory.
Göttingen, Royal Academy of Sciences.
Göttingen, Royal Observatory.
Halifax, Nova Scotian Institute of Sciences.
Halle, Imperial Leopold-Caroline Academy.
Hamburg Observatory.
Harvard College Astronomical Observatory.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
International Committee of Weights and Measures.
International Geodetic Association.

Italian Meteorological Society.
Kasan, Imperial University.
Kasan Observatory.
Kiel, Royal Observatory.
Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Lund Astronomical Observatory.
Madras, Government Observatory.
Madrid Observatory.
Manila Observatory.
Mauritius, Royal Alfred Observatory.
Melbourne, Government Observatory.
Milan, Royal Lombard Institute of Sciences.
Moncalieri Observatory.
Montevideo, International Solar Institute.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
New Haven, Connecticut Academy of Arts and Sciences.
New York, Columbia University Observatory.
O-Gyalla, Astrophysical and Meteorological Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Meteorological Service of the Dominion of Canada.
Padua Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, Mathematical Society of France.
Paris, Ministry of Public Instruction.
Paris Observatory.
Paris, Philomathic Society.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Philadelphia, University of Pennsylvania.
Pola, Meteorological and Magnetical Observatory.
Potsdam, Astrophysical Observatory.
Potsdam, Central International Geodetic Bureau.
Potsdam, Royal Prussian Geodetic Institute.
Poulkova Observatory.
Prague, Imperial Observatory.
Queensland Branch of the Geographical Society of Australasia.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.

Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *de' nuovi Lincei.*
Rome, Royal Academy *dei Lincei.*
St. Petersburg, Imperial Academy of Sciences.
St. Petersburg, Russian Astronomical Society.
San Fernando Observatory.
San Francisco, Astronomical Society of the Pacific.
Stockholm, Royal Swedish Academy of Sciences.
Strassburg, Imperial University Observatory.
Sydney, Government Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya, National Astronomical Observatory.
Tiflis, Physical Observatory.
Toronto, Astronomical and Physical Society.
Toronto, Canadian Institute.
Toulouse, Academy of Sciences.
Turin, Royal Academy of Sciences.
Turin, Royal Astronomical Observatory.
Upsala Observatory.
Upsala, Royal Society of Sciences.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Austrian Geodetic Bureau.
Vienna, Imperial Military Geographical Institute.
Vienna, Imperial Ministry of Marine.
Vienna, Imperial University Observatory.
Vizagapatam, G. V. Juggarow Observatory.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Smithsonian Institution.
Washington, United States Naval Observatory.
Yale University, Astronomical Observatory.
Yerkes Observatory.
Zürich, Central Meteorological Institute of Switzerland.
Zürich, Geodetic Commission of Switzerland.
Zürich, Society of Natural History.
Zürich Observatory.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of "Astronomische Mittheilungen."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
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Editors of "The Observatory."
Editors of "Popular Astronomy."
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ADDRESS

Delivered by the President, Professor G. H. Darwin, on presenting the Gold Medal of the Society to M. H. Poincaré.

THE medal of the Royal Astronomical Society is this year awarded to M. Henri Poincaré, member of the Academy of Sciences of Paris. As your President, the agreeable duty of presenting the medal to him devolves upon me, but before I do so I must endeavour to lay before you the grounds upon which the Council has made this award.

M. Poincaré's researches have been so diverse in character, and have been carried out with such a wealth of knowledge, that I feel but little confidence in my fitness to perform this arduous task; yet I cannot but rejoice that my tenure of this chair should have furnished me with the opportunity of paying the homage which is due to him for his great achievements in the field of mathematics.

A large part of his work is concerned with the development of the science of pure mathematics, and of this side of his activity I am quite incompetent to speak. But in awarding our medal we naturally think of the value of the contributions by the proposed medallist to our science. Now, although many of M. Poincaré's investigations have perhaps already found, or will at some future time find, their application in the problems of dynamical astronomy, yet it is not necessary to search for cases of possible applicability to astronomy to justify our award. I propose, then, to draw your attention to only three of his lines of research, and these have a directly astronomical scope. My choice is governed not only by the intrinsic interest of the results, but also by the fact that the subjects treated possess a special interest for me. I shall speak, then, of his researches on the dynamical theory of the tides, on figures of equilibrium of rotating masses of liquid, and on the theory of the motions of planets and satellites.

The first of these subjects is treated in two memoirs on the equilibrium and movement of the ocean.* The problem is surrounded by conditions of such intricacy that it seemed to the author advisable to consider the several difficulties separately, as a preliminary to the treatment of the question as a whole. He begins, then, by the equilibrium theory of the tides, but he

* *Liouville's Journal*, 1896, pp. 59–102, and pp. 217–62.

proposes to take into account not only the effect of the obstructing continents, but also that of the attractions of the sea on itself. This problem was solved long ago by Bernoulli for the case when there is no land, and some thirty years ago by Lord Kelvin when there is no mutual attraction of the water on itself.* Lord Kelvin's correction to Bernoulli's theory may be taken as meaning that there are on a certain complete meridian four points at which the semi-diurnal tide vanishes; two of these points are on the same side of the Earth in equal northern and southern latitudes, and the others are antipodal to the first two. There are also four other points on another complete meridian where the diurnal tide vanishes; two of them are in one quadrant in complementary latitudes, and the other two are antipodal to the first two. Lastly, there are two parallels of equal northern and southern latitude at which the tides of long period are evanescent. There are, further, four other points of doubled semi-diurnal tide, four of doubled diurnal tide, and two parallels (sometimes, however, imaginary) of doubled tide of long period.

The positions of these points and parallels are dependent on the distribution of land and sea. The numerical quadratures necessary for their determination have been carried out, and it appears that in every case the points or lines of evanescence or of doubling lie very close to the places where the tide in question absolutely vanishes in Bernoulli's theory.† Since it can make very little difference whether a tide of excessively small range is doubled or annulled, it follows that the correction for land is of little importance, at least when the attraction of the water is neglected.

The introduction of the effects of the mutual attraction obviously presents a problem of great difficulty. Although it is probable that the result would possess little practical importance, yet the question is undoubtedly an interesting one from a mathematical point of view. It is at this point that M. Poincaré takes up the problem, and he shows that it is possible, at least theoretically, to determine a series of harmonic functions by which the mutual gravitation of the ocean may be computed. These functions degrade into ordinary spherical harmonics when the land is all submerged. Lord Kelvin had expressed the opinion that mutual attraction would only change the results to an insignificant degree, but M. Poincaré, while not contesting the justice of this view in general, adduces considerations which seem to show that a distribution of land is imaginable, which might perhaps make the correction of material importance. But the verification of this conjecture would necessitate the complete calculation, which would present an absolutely inextricable complexity on account of the capricious forms of our continents.

Although it does not seem likely that these new harmonic

* Thomson and Tait, *Nat. Phil.* § 808.

† G. H. Darwin and H. H. Turner, *Proc. R.S.* 1886, vol. xl. pp. 303–15.

functions will ever be applied to terrestrial oceans, yet they may perhaps furnish a clue to the discussion of the tides of seas of simple forms, such as the quadrant or octant of the whole globe.

The author's next step is the discussion of the small free oscillations of a system about a configuration of equilibrium, and we are here concerned with principles of the widest generality. He proves that the problem of small oscillations resolves itself into the determination of the maxima and minima of the ratio of the kinetic to the potential energy; and the transition is easy from the case of free oscillations to that of forced oscillations under the action of any perturbing forces. This generalisation forms the basis of the author's whole investigation, and he remarks that he found the first suggestion of it in the work of Lord Rayleigh.

Passing from the case of a finite number to that of an infinite number of degrees of freedom, the author then applies his general principle to the oscillations of liquid standing in a vessel of small dimensions. The vessel is then enlarged so that the free surface at rest cannot any longer be treated as plane, but must be considered as a portion of a sphere concentric with the Earth's centre. It appears that the mathematical analysis is the same as that involved in finding the oscillations of a stretched membrane of unequal density and thickness in its different parts. This problem had been previously treated by the author in another memoir.

This brings us to the end of the first paper, and the second begins with the discussion of the process called by Lord Kelvin the ignoration of coordinates. The so-called gyroscopic terms now appear in the equations of motion; in the tidal problem they arise through the fact of the Earth's rotation, and they form a very essential feature of the whole.

The general principles of the motion in such cases are then applied to the consideration of the oscillations of liquid standing in a small rotating vessel. This problem had been treated previously by Lord Kelvin; * and he found, amongst other results, that waves propagated along a rotating canal would behave differently on the right and left banks. In this he saw a probable explanation of the different behaviour of the tides on the south coast of England and on the north coast of France. Well, the tides on the coasts of the two countries do not differ so much as the treatment which the problem presented by them has received from Lord Kelvin here and from M. Poincaré in France. As might be expected, the latter obtains his solution from the maxima and minima of a certain ratio, which corresponds to that between the kinetic and potential energies in the simpler problems treated before.

* *Proc. R.S. Edinburgh*, 1879 March 17, or *Phil. Mag.* 1880 August, pp. 109–116.

The problem of the rotating vessel only differs from that of the tides in all its generality in the linear scale on which it is supposed to take place; and the effects of the Earth's curvature may be introduced in the same way as in the case of the non-rotating vessel.

The object of these memoirs was not to attain a definite solution in any ideal concrete case, but was to show how the fundamental difficulties might be surmounted by mathematical analysis. Here, as elsewhere, M. Poincaré carries us far beyond the particular instance in view, and it may well be that the principles enounced will meet their actual application sooner in other fields than in the tidal problem.

Important as is the work of which I have just spoken, the memoir on the figures of equilibrium of rotating liquid * seems to me to stand on a much higher level, for it marks an epoch not only in the study of the subject itself, but also in that of many others. It may be that some of the generalisations to be found in it were floating more or less distinctly in the minds of his predecessors, but the theory of the stability of systems in equilibrium or in steady motion has undoubtedly been crystallised and rendered transparent by his efforts. So fundamental are the new conceptions introduced that a new phraseology has become necessary, and it has already been adopted in other investigations, which possess no superficial resemblance to that of which I am now speaking.

Let us imagine a number of mechanical systems which resemble one another in all respects save one, such as size or density or any other measurable quantity. Suppose, further, that the systems are all in equilibrium, and that they are arranged in the order of the magnitude of that one measurable quantity, then we may describe the whole array as a family of systems in equilibrium. Now mechanical systems are often susceptible of equilibrium in more than one configuration, and we may therefore conceive the existence of a second family, which differs from the first in that the equilibrium involves a different configuration of the parts. If we were to examine the two families, we should find that in each the arrangement of the parts changed as we passed along the series. Now it is possible that there would occur in one family a certain member which would resemble the corresponding member of the other family in all respects. If this were the case, this particular member of either family would be described as a form of bifurcation, because it would belong to both, and the two families might be regarded as branching out from it. Now, M. Poincaré proves that if we follow each family towards the form of bifurcation, the equilibrium in one of the families would be stable, while that in the other would be unstable; the same would also hold good after the passage through the form of bifurcation, but the family which was stable

* *Acta Mathematica*, vii. 1885-6, pp. 259-380.

before would be unstable afterwards, and *vice versâ*. There is accordingly exchange of stabilities between the two families. Moreover, the passage of a system from stable to unstable equilibrium necessarily implies that at the moment of change we are passing through a form of bifurcation. Hence the study of the stability of a system may afford notice of the existence of hitherto unsuspected arrangements in which equilibrium is possible. These ideas possess the widest generality, but this is not the place to discuss their fertile ramifications.

If a system in steady motion or one at rest be slightly disturbed, it is said to be stable if the oscillations continue to be small throughout all time. But the existence of even the smallest amount of frictional resistance may betray the fact that stability really means two very different things. In one case even infinitesimal frictional resistance may cause the oscillations to increase to such an extent as to completely change the whole configuration; in another the oscillations may gradually die out and leave the system in the same condition as that in which it was at first. Both systems are stable when there is no friction, but the latter is said to possess secular stability. In nature only systems possessing secular stability are permanent, although it may require a very long time for a system possessing ordinary stability to break down. M. Poincaré here pays a well-merited tribute to Lord Kelvin, who appears to have been the first to clearly indicate this important distinction between these two kinds of stability.

Thus far the discussion is applicable to mechanical systems of every kind, but it finds its special application in the determination of the figures of rotating fluid. It may be well to mention, by the way, that in the course of the paper M. Poincaré justifies a number of statements as to possible forms of equilibrium and their stability, which had been made by Lord Kelvin without proof.

We now come to the main object of the investigation. A planet formed of homogeneous fluid has the form of an oblate spheroid, and its equilibrium is stable. If its angular velocity of rotation be increased, its ellipticity will increase also, but the stability will diminish. When the ellipticity has increased to a certain definite extent, the stability ceases, and for more rapid rotation the figure becomes unstable. At the critical moment of change we are passing through a form of bifurcation, and we know that there must be another series of figures which also possesses that form. This other series consists of the ellipsoids of Jacobi, which have their three axes of unequal magnitudes. But there is one single member of Jacobi's series which is a figure of revolution, and this is identical with the form of bifurcation found by following the stability of the oblate figures. It is true that this Jacobian is also a limiting form, since the series ends there; but we need not stop to consider that point further. It follows from the principle of exchange of stabilities that for rotation slower than

the critical value the Jacobian was stable. All this was known before, but M. Poincaré's work has placed it in a new and clearer light.

Having followed the stable series of oblate ellipsoids of revolution up to the junction at the form of bifurcation, M. Poincaré shunts his train on into the stable branch line furnished by the Jacobian ellipsoids. He follows this branch until he finds the Jacobian to become unstable, and announces that there is a new form of bifurcation, and that a new branch line has been reached. And here the line is nearly blocked by mathematical obstructions, and he is only able to proceed just far enough to perceive that the new figure is pear-shaped, with its larger portion more or less spherical, and with an equatorial protuberance which we may liken to the stalk end of the pear.

This apparently abstract result elucidates the evolution of planetary systems in a very interesting way. Let us consider a rotating liquid mass slowly cooling. If the cooling is slow enough internal friction will cause the whole to revolve throughout with the same angular velocity. At first, when the density is small, the figure will be an ellipsoid of revolution, but slightly flattened ; and as it cools the flattening will increase until at a certain stage the figure of revolution ceases to be a figure of equilibrium, and the ellipsoid commences to have an equatorial protuberance ; it passes, in fact, into one of Jacobi's ellipsoids. The ellipsoid then lengthens, until at a certain stage it begins to acquire an unsymmetrical furrow in a plane parallel to the axis of revolution, and it becomes pear-shaped, with the axis of revolution at right angles to the core of the pear. "The larger part of the matter tends to approach the spherical form, whilst the smaller part projects from the ellipsoid at one of the extremities of the longer axis, as though it were trying to detach itself from the larger part of the mass. It is difficult to state with certainty what will happen then if the cooling continues, but one may suppose that the mass will go on deepening its furrow more and more, and then it will at last divide itself into two separate bodies by the throttling of the middle part." It is clear that a process of this kind may have played its part in the evolution of celestial systems, and the speculation seems to meet with confirmation from the forms observed in many nebulæ.

M. Poincaré's paper came as a revelation to me, because, just at the time when it was published, I had attempted to attack the question from the other end, and to trace the coalescence of two detached bodies into a single one—but, alas ! I have to admit that my work contained no far-reaching general principles —no light on the stability of the systems I tried to draw— nothing of all that which renders Poincaré's memoir one that will always mark an important epoch in the history not only of evolutionary astronomy, but of the wider fields of general dynamics.

I now come to the third contribution of our medallist to

astronomy, namely the work on celestial mechanics. The first of the three volumes * of which the book consists deals with the general principles of dynamics as applicable to the problem of the three bodies, the second is on the work of previous investigators, and in the third the author analyses the results at which he has arrived by the previous discussions. It is probable that for half a century to come it will be the mine from which humbler investigators will excavate their materials. The range of matter is so vast and the number of new ideas so great, that I find myself in considerable difficulty as to how to speak of this book. It would clearly be impossible within the limits of such an address as this to give even an outline of the methods and conclusions.

Under these circumstances, then, I shall limit myself to only one portion of the whole, and shall speak of that at no great length. The subject to which I refer is that of the so-called periodic orbits; and my choice is natural, since I have been myself a hewer of wood and drawer of water in that field.

It was Mr. G. W. Hill who first drew effective attention to this class of solutions of the problem of the three bodies, when he initiated his new method of treating the lunar theory.† I am proud to say that our Fellow, Mr. Ernest Brown, is now carrying on Hill's grand conception to its laborious end. Former mathematicians have, almost without exception, adopted the Moon's elliptic orbit as their starting-point. But the first and roughest approximation to the Moon's path is a circle round the Earth, and the ellipse is an attempt to improve on the circle. Now Hill saw that the early introduction of the ellipse brought in its train a whole series of difficulties, which would be avoided if, continuing to neglect the eccentricity, he improved on the circle by introducing at once the effects of solar perturbation. The distorted circular orbit possesses the great advantage that it always presents the same features towards the Sun and the Earth. It is accordingly possible to draw, with any desired accuracy, a certain definite curve on a plane carried round with the Earth in its orbital motion. This curve exhibits the leading features of the effects of solar perturbation for all time; it resembles an ellipse drawn about the Earth as centre, with the major axis in quadratures, and with the minor axis in syzygies. The principal solar inequality is the variation, and hence Hill describes this orbit as the variational curve, and he uses it as an orbit of reference for the Moon's actual motion. If the Moon had been started with a motion differing but little from actuality she would have followed the variational curve for all time.‡ The curve may then be appropriately termed a periodic orbit.

* *Les Méthodes Nouvelles de la Mécanique Céleste.* Paris, Gauthier-Villars. Vol. i. 1892, vol. ii. 1893, vol. iii. 1899.

† *Researches in the Lunar Theory*, Cambridge, U.S.A. 1877.

‡ Hill's simple variational curve was drawn on the hypothesis that the squares and higher powers of the Sun's parallax are negligible. But these

Hill afterwards introduced the eccentricity of the lunar orbit by reference to the variational curve, and he treated the subject by a fertile method of the highest originality.* He habitually restrains himself from every tendency towards exuberance of expression in his writing, and so I am perhaps deceived when I fancy that even he hardly realised the fundamental importance of what he had done. Speaking of Hill's papers, M. Poincaré writes: "Dans cette œuvre il est permis d'apercevoir le germe de la plupart des progrès que la science a faits depuis." † Although he also pays warm tribute to Gyldèn and to Lindstedt, I conjecture that it may have been Hill who stimulated him to his attack on the profound questions awaiting solution in celestial mechanics. But these are almost personal questions which have little bearing on the advance of science in itself.

The variational curve obviously does not stand isolated, but is merely a single member of a series of periodic solutions of the problem of the three bodies. These solutions, according to M. Poincaré, furnish the only breach by which we may hope to penetrate the fortress of a problem hitherto deemed impregnable. Their importance becomes manifest when I say that he has proved that a periodic solution may always be found which shall differ by as small a quantity as we please from any given motion of the perturbed body, however complicated that motion may be. It is true that the required periodic orbit may need to go through a very large number of circuits before its periodicity is completed.

Orbits of this kind are divisible into three classes: in the first, the inclinations and eccentricities are zero; in the second, only the inclinations are zero; and in the third, there are no limitations in these respects. In the cases of the variational curve and of the orbits which I have traced, the orbit of the perturbing body is circular, the whole motion takes place in the plane of the circle, and the periodicity of the perturbed body is completed after a single circuit; they belong to the first group. As in the investigation of figures of equilibrium, so here also we meet with orbits of bifurcation, limiting forms and exchanges of stability; and this illustrates the wide generality of the ideas which I attempted to sketch earlier in my address.

Mr. Hill had traced a certain cusped orbit in which the Moon might have moved, and thinking that he had found a limiting form, described it as the Moon of greatest lunation. But M. Poincaré showed that Hill had been misled, and that the cusp is succeeded by looped orbits. Lord Kelvin chose one of them

further approximations may be introduced, and the above statement then becomes correct. The simple curve is symmetrical both as to the lines of syzygies and of quadratures, but the corrected curve is only symmetrical as to syzygies.

* "On Part of the Motion of the Lunar Perigee, &c.," *Acta Mathematica*, vol. viii. pp. 1–36.

† *Méc. Céleste*, vol. i. Introduction.

as an example to illustrate a method of graphical construction by which a curve may be traced by means of its curvature.* The successive transformations of these orbits are elucidated by the series of figures which I have drawn, and I now see that they will terminate their career, at least as simply periodic orbits, in a form which has been called by M. Burrau an orbit of ejection.† As this latter name is hardly sufficiently explanatory in itself, I may say that the perturbed body is supposed to be ejected from one of the two principal bodies along the line of syzygies, or it may fall inward tangentially to that line. These orbits furnish an interesting and peculiar form of periodicity, but the limitation of my time prevents me from referring to them in greater detail.

Another class of orbits, as pointed out by Poincaré, is said to be asymptotic; they are closely akin to the periodic orbits. In this case the body draws asymptotically near to a certain curve, and after performing an indefinite number of circuits, may gradually depart therefrom again. Certain figure-of-eight orbits which I have drawn are intimately connected with these asymptotic orbits.

M. Poincaré has made a searching examination of my figures by means of his analysis, and has put his finger on a weak spot. I had carelessly treated two sets of curves as being continuous with one another, but he shows that my scheme cannot be maintained. I had already arrived at the same conclusion from an entirely different point of view in consequence of the criticism of Mr. S. S. Hough, but it was too late to correct the oversight before the paper was published. Mr. Hough has now a paper in the press for the *Acta Mathematica*, wherein the true sequence of the orbits will be exhibited. I have already by me a large part of the computations required for the actual drawing of a new family of orbits, whose existence I did not suspect.

There can, I think, be little doubt that the investigations of M. Poincaré and of his followers will ultimately afford some sort of explanation of the empirical law of Bode as to the distances of the planets from the Sun; and such an explanation will almost of necessity render intelligible the sequence of processes by which the solar system has been evolved. In the case of the satellites revolving about my ideal planet *Jove* I found that there was a tract near the planet which might be occupied by stable orbits, that this was surrounded by a belt, within which no stable orbit was possible, and that this was again succeeded by a belt of stability. These results are, of course, only true of simply periodic orbits; and I was perhaps rash in saying that I saw in them some indications of a law analogous to that of Bode. Nevertheless, I notice also in M. Poincaré's book a suggestion which may perhaps tend in the same direction. The inferior planets circling round the Sun in my ideal problem were stable up to a certain

* *Phil. Mag.* vol. xxxiv. 1892, pp. 443–8.
† *Ast. Nachr.* Nos. 3230 and 3251.

distance, and then became unstable, and he conjectures that the further pursuit of this family of orbits will lead us back again to a belt of stability. I hope to test this interesting suggestion. But even this meagre sketch has already occupied too much time, and I will say but few words more.

The leading characteristic of M. Poincaré's work appears to me to be the immense wideness of the generalisations, so that the abundance of possible illustrations is sometimes almost bewildering. This power of grasping abstract principles is the mark of the intellect of the true mathematician; but to one accustomed rather to deal with the concrete the difficulty of completely mastering the argument is sometimes great. To the latter class of mind the easier process is the consideration of some simple concrete case, and the subsequent ascent to the more general aspect of the problem. I fancy that M. Poincaré's mind must work in another groove than this, and that he finds it easier to consider first the wider issues, from whence to descend to the more special instances. It is rare to possess this faculty in any high degree, and we cannot wonder that the possessor of it should have compiled a noble heritage for the men of science of future generations.

In handing this medal to you, M. Poincaré, I desire to say on behalf of the Society that in seeking to pay honour to you we feel ourselves honoured.

The meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

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A. A. Common, Esq., LL.D., F.R.S.
G. H. Darwin, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
H. H. Turner, Esq., M.A., B.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

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W. H. M. Christie, Esq., C.B., M.A., F.R.S., Astronomer Royal.
A. M. W. Downing, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac.*
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.
Capt. E. H. Hills, R.E.
Frank McClean, Esq., M.A., LL.D., F.R.S.
Major P. A. MacMahon, R.A., F.R.S.
Capt. William Noble.
A. A. Rambaut, Esq., D.Sc., Radcliffe Observer.
G. M. Seabroke, Esq.
E. J. Spitta, Esq.
W. G. Thackeray, Esq.
E. T. Whittaker, Esq., M.A.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. MARCH 9, 1900. No. 6

E. B. KNOBEL, Esq., PRESIDENT, in the Chair.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Alexander Foote, F.S.A. Scot., Mall Park, Montrose, Scotland; and 111 Warwick Road, Earl's Court, S.W. (proposed by A. Fowler).

Désiré Ernest Lebon, Agrégé de l'Université, Professeur de mathématiques au Lycée Charlemagne, 4 bis, rue des Écoles, Paris (proposed by C. Flammarion).

One hundred and fifteen presents were announced as having been received since the last meeting, including amongst others:—

Al Battani, Opus Astronomicum, presented by the Milan Observatory; Astronomical and Astrophysical Society of America, First meeting, presented by the Society; Th. Brédikhine, Sur les radiants composés (dits stationnaires) des étoiles filantes, presented by the author; Galileo, Opera, vol. 8, presented by the Italian Government; Sir William and Lady Huggins, Atlas of representative stellar spectra, presented by the author; Rev. S. Kinns, 'Six Hundred Years,' presented by the author; Königsberg Observatory, Beobachtungen, Abth. 18, 19, presented by the Observatory; F. X. Kugler, Die Babylonische Mondrechnung, presented by the author; W. T. Lynn, Remarkable

Comets, 7th edition, and Remarkable Eclipses, 4th edition, presented by the author; L. Weinek, Photographischer Mond-Atlas, Heft 4–6, presented by Professor Weinek; E. T. Whittaker, Report on the progress of the solution of the problem of three bodies, presented by the author; Bronze copy of the Stokes Jubilee Medal, presented by the University of Cambridge.

On the Binary System of Capella. By H. F. Newall.

A very brief announcement of the discovery of the binary character of *Capella* was made in a note communicated to the Society in 1899 November (*ante*, p. 2). A similar announcement was made by Professor Campbell, of the Lick Observatory, in the October number of the *Astrophysical Journal* (vol. x, p. 177). Two brief communications have been made to the Observatory (1900 February, pp. 92, 93). The object of the present note is to lay before the Society the result of a preliminary investigation of the photographs of the spectrum of *Capella* which have been obtained at Cambridge.

A new four-prism spectroscope was attached to the 25-inch equatorial in 1899 July. Some of the earliest photographs obtained with it were spectra of *Capella*; and it was at once noticed that the definition appeared poor and unsatisfactory. From night to night it varied in a curious manner; and it became clear that the peculiarities were real, and not due to instrumental defects, for excellent photographs were obtained of the spectra of other stars—notably of *Procyon* and *Sirius*.

After a preliminary study of ten or twelve photographs of the spectrum of *Capella*, it seemed clear that the spectrum was composite, and lines were picked out as belonging to one component, which we will call the solar component, and other lines as belonging to another component, which in the short range of spectrum dealt with has the characteristics of the spectrum of *Procyon* and γ *Cygni* and α *Persei*; it will be convenient to refer to it in what follows as the *Procyon* component. It is difficult to make out the spectrum; and I think it not unlikely that this choice of name may require revision.

Measurements were then made in the short range of spectrum $\lambda\lambda$ 4250–4325; and the results in the case of the solar component are given in the following table, and are plotted in the accompanying plate; ordinates representing the velocity of that component relative to the Sun, with time as abscissa. The curve drawn through the observations is a sine curve, to which further reference will be made below. In the table the first column contains the plate number, the second the date, the third the duration of exposure, the fourth the velocity deduced from the photograph (*i.e.* the velocity relative to Earth), the fifth the

correction for orbital motion of the Earth, and the last column the velocity relative to the Sun.

Velocity of Solar Component of α Aurigæ.

	1899.	G.M.T.	Exp.	Vel. rel. to ⊕	Corr. to ⊙	Vel. rel. to ⊙
F. 21	Sept. 28	12.20	60	−23·5	+26·3	+ 2·8
F. 22	Oct. 2	12.19	60	−18·2	+25·7	+ 7·5
F. 32	16	10.58	75	+ 8·3	+22·8	+31·1
F. 33	17	10.30	75	+ 3·2	+22·6	+25·8
F. 34	18	10.54	75	+12·4	+22·3	+34·7
F. 38	Nov. 1	9.55	62	+33·2	+17·9	+51·1
F. 39	6	9.12	75	+34·4	+16·0	+50·4
F. 40	6	10.43	63	+37·3	+16·0	+53·3
F. 44	8	9.56	62	+37·9	+15·2	+53·1
F. 46	10	9.17	70	+41·1	+14·4	+55·5
F. 48	11	10.15	60	+41·8	+14·0	+55·8
F. 49	17	9.16	60	+39·6	+11·4	+51·0
F. 50	20	9.40	60	+39·6	+10·1	+49·7
F. 54	23	9.16	70	+37·8	+ 8·8	+46·6
F. 56	28	8.45	70	+32·3	+ 6·5	+38·8
F. 58	Dec. 1	8.47	70	+27·8	+ 5·1	+32·9
F. 62	2	9.6	60	+28·3	+ 4·6	+32·9
F. 64	11	6.40	50	+22·7	+ 0·3	+23·0
	1900.					
F. 67	Jan. 9	5.57	62			
F. 71	17	12.6	60	+26·6	−16·9	+ 9·5
F. 72	18	12.34	63	+30·1	−17·3	+12·8
F. 73	20	12.22	70	+38·1	−17·8	+20·3
F. 76	24	12.30	70	+42·8	−19·3	+23·5
F. 79	27	11.10	70	+48·4	−20·3	+28·1

The method adopted in deducing the velocity was as follows : The wave-lengths of the chosen lines in the spectrum of the star were determined with reference to the lines in the comparison spectrum of the iron spark, interpolation being performed by means of the relation $\lambda-\lambda_0=c/(R_0-R)$, to which Dr. Hartmann has called attention recently. The three constants, λ_0, c, R_0, are determined from three standard lines in the iron-spark spectrum.

The linear dispersion of the spectra obtained with the instrument is approximately six tenth-metres per millimetre, or 1·5 tenth-metres per revolution of the micrometer used for measuring the spectra. Wave-lengths of lines in the spectra can be determined with reference to the comparison spectra of the iron spark to within about 0·02 of a tenth-metre.

The same three standard lines in the iron-spark spectrum have been used in the reduction of all the plates; hence any error that may be introduced by assigning to them the wave-lengths given by Rowland for the corresponding lines in the solar spectrum instead of values of wave-lengths in which account is taken of the effects of pressure in the spark, affects all the plates approximately equally.

Thus, in the plate F. 39, taken 1899 November 6, the following wave-lengths were deduced for chosen lines in the star spectrum:

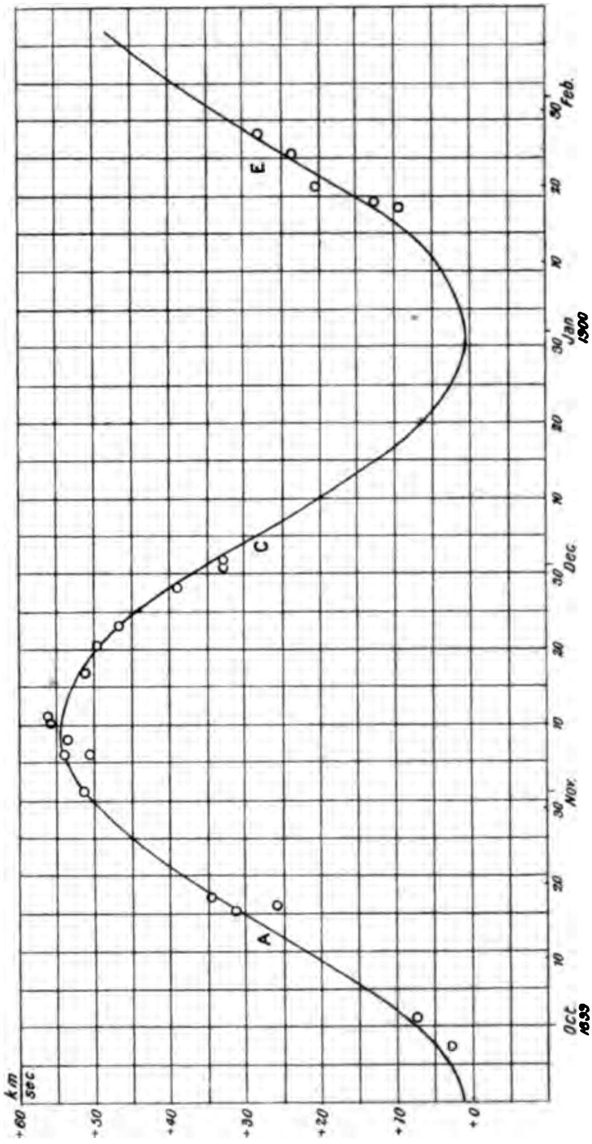
Wave lengths (affected by velocity) of the Star-lines	Wave lengths in Rowland's Tables of Solar Spectrum.	Shift of Line $\delta\lambda$.	Corresponding Velocity.
4275·47	4274·99	+0·48	+33·7 km/sec
76·25	75·68	0·57	40·0
88·77	88·21	0·56	39·1
92·79	92·30	0·49	34·2
93·85	93·28	0·57	39·8
94·77	94·25	0·52	36·3
95·67	95·28	0·39	27·3
4302·13	4301·67*	0·46	32·1
07·07	06·59*	0·48	33·5
14·77	14·34	0·43	30·0
15·59	15·13	+0·46	+32·0
		Mean	+34·4

Correction for Earth's orbital velocity +16·0

Velocity relative to ⊙ ... ... +50·4 km/sec.

The velocities come out very consistently considering the difficulties in deciphering the superposed and shifted spectra of the two components. It will be realised that twice in each period the superposed spectra are coincident, line for line; the lines appear single and distinct, and the spectrum looks in nearly all respects like a well-defined solar spectrum. This occurs when the velocities of the two components are alike, namely, near the points marked A, C, E on Plate 11. At all other times the spectrum looks more or less ill-defined in a curious way; some lines look double, others are at first sight unexpectedly intensified, others apparently obliterated. Enlarged transparencies of well-defined single spectra have been made (i.) of the Sun, (ii.) of *Procyon*; when they are superposed on one another, the films being in contact, one spectrum can easily be shifted relatively to the other, and the resultant spectrum has been found to reproduce all the above-described effects in a very striking

* Bright spaces between absorption lines, wave-lengths determined in terms of Rowland from separate photographs.



Velocity of Solar Component of the binary Capella.

manner. A cursory inspection of the various combinations has been very helpful in guiding one to the choice of lines suitable for measurement. One of the most curious effects brought out is the apparent obliteration of certain groups of lines when the two spectra are appropriately shifted, relatively to one another.

The measurements relating to the *Procyon* component are somewhat difficult, and unfortunately there was a spell of cloudy weather at an important phase of the observations, when the two spectra were shifted relatively to one another in such a way that it would probably have been least difficult to decipher the spectrum of that component. I therefore defer dealing with the motion of the *Procyon* component, and will here only state that it appears to be such as to lead me to think that the masses of the two components are not very different from one another. Furthermore, the relative distinctness of the two superposed spectra points to the probability that the two components do not differ much in brightness.

It is seen that the sine curve appears to satisfy the observations fairly well, but there is evidence that a better curve could be found. The orbit is consequently not quite circular, but nearly so.

A period of 104 days is deduced from the observations of the solar component. Passing the same curve through the velocities deduced by Professor Campbell from photographs taken in 1897, it is easy to pick out corresponding phases. A second approximation to the period is thus obtained, 104·0 days.

Here may be noted an interesting point connected with the Potsdam observations of *Capella* in 1888. It will be remembered that specially careful determinations were made of the velocity of this star, and the concordant results deduced may now clearly be taken as indicating the constancy of the motion of translation of the whole system of *Capella*. From twelve photographs taken between 1888 October 6 and 1889 September 15, Dr. Vogel made twenty-five determinations, and Dr. Scheiner fourteen determinations of the velocity with the definitive results:

Vogel	+24·8 km/sec.
Scheiner	+24·1 km/sec.

The velocity of the system at the present time is +27 or +28 km/sec.

It was the custom of the Potsdam observers to give a note of the general appearance of the photographs measured; and some of the spectra obtained were described as good, and others as "verwaschen" or "unscharf," and in one case Dr. Vogel ascribes the want of definition to the faulty setting of the camera.

In determining the wave-lengths of the lines in *Capella* Professor Scheiner made use of two photographs, each of which he describes as "ganz ausgezeichnetes Spectrum" (*Potsdam Obs.*,

vol. vii., page 257), one taken 1888 October 24 and the other 1888 December 13. It appears that photographs were also obtained on October 22 and on October 25, and that the photograph of October 24 may have been picked out as the best-defined spectrum. Possibly, then, October 24 was an epoch when the velocities of the two components were equal. If so, then the second photograph should correspond with an epoch 52 or 104 days later. The interval between October 24 and December 13 is 50 days, an agreement which may be taken as satisfactory, when it is borne in mind that at the epoch considered the width of the lines in the spectrum increases only at the rate of 0·02 tenth-metre per day.

Again, if the above inference is justifiable and the period 104 days is constant, then the interval between 1888 October 24 and 1899 December 6, which latter date is the epoch in my observations when the velocities were found to be equal and the definition of the spectrum at its best, should be either an exact number of periods or should differ from it by half a period. Now, the interval is 4060 days, or $39{\cdot}04 \times 104$ days. Hence we might arrive at another approximation to the period, viz. 104·1 days; but these are somewhat risky foundations, either for an accurate determination of the period of the system or in support of the view that the period has remained constant.

As to the system of *Capella*, one or two interesting points may be noted.*

The spectroscopic observations show

I. That the components are nearly equal in mass.

II. That the components are not very different in brightness.

III. That the radius of the relative orbit is at least 52,000,000 miles. This is the smallest orbit consistent with the spectroscopic observations; it corresponds to the case when the orbital plane is seen "edge on." Such an orbit would involve eclipses of one component by the other, and consequently also variability in brightness; but no sign of variability has been detected in *Capella*. If the orbit is inclined so that the angle between its normal and the line of vision is i, then the radius of the orbit is $52 \times 10^6/\sin i$ miles.

Let a=actual radius of the relative orbit= $52 \times 10^6/\sin i$
s=maximum telescopic separation of the components expressed in seconds of arc (not yet observed)
D=distance of the system from the Sun
R=distance of the Earth from the Sun
p=parallax expressed in seconds of arc;

then we have $$\frac{a}{D} = s \, . \sin 1''$$

* In this connection reference should be made to an interesting note by Miss Clerke in *The Observatory*, 1900 March, p. 127.

and $$\frac{R}{D} = p \cdot \sin 1'' ;$$

whence $$a = \frac{sR}{p} = \frac{52 \times 10^6}{\sin i}$$

or $$\frac{s \cdot \sin i}{p} = \frac{52}{93}.$$

Now, Dr. Elkin gives for the parallax of *Capella* the value 0″·08. And *Capella* has not been observed telescopically as a double-star; its components are therefore presumably less than 0″·1 apart. Hence we infer that to make the spectroscopic observations fit with these data, we must have

$$\sin i > \frac{8 \times 52}{10 \times 93}, \text{ or } \cdot 447,$$
$$\text{or } i > 27^\circ.$$

Even when $i = 90^\circ$, the maximum telescopic separation of the components, if Elkin's parallax be accepted, must be at least 0″·04.

With respect to the mass of the system, let

M = the mass of the solar component,
nM = the mass of the *Procyon* component,
U = the period of the binary system.

Then we have $$M = \frac{a^3(1+n)^2}{U^2}.$$

Since the solar component moves with an orbital velocity of $\frac{27}{\sin i}$ km/sec we deduce that the radius of its orbit (assumed circular), is

$$a = \frac{38 \cdot 6 \times 10^6}{\sin i} \text{ kilometres or } \frac{24 \times 10^6}{\sin i} \text{ miles.}$$

Hence the mass of the *Capella* system is

$$(1+n)\,M = \frac{24^3}{93^3} \cdot \frac{365^2}{104^2} \cdot \frac{(1+n)^3}{\sin^3 i} \times \text{Sun's mass}$$
$$= 0 \cdot 212 \times \frac{(1+n)^3}{\sin^3 i} \times \text{Sun's mass.}$$

And if, accepting I, we put $n = 1$, we have

$$\text{mass of } Capella \text{ system} = \text{Sun's mass} \times \frac{1 \cdot 7}{\sin^3 i} ;$$

and, accepting Elkin's parallax, and assuming that the components are less than 0″·1 apart, we have

$$\text{mass of } Capella \text{ system} < 19 \times \text{Sun's mass.}$$

With reference to the brightness of *Capella*, we have the following considerations:—If the Sun were removed to the distance of *Capella*, it would appear 32 magnitudes fainter than at its present distance. Taking the Sun's magnitude as $-25{\cdot}5$, and *Capella's* as $+0{\cdot}2$, we find

Capella's brightness=480 times the Sun's brightness.

If the components are equal and have the same intrinsic brightness of surface as the Sun, it would appear that each component must have a diameter about 15 times that of the Sun. In this case eclipses could only be avoided if the angle between the normal to the orbit and the line of sight is not greater than that value which satisfies the equation $\frac{15\times 8\times 10^5 \sin i}{52\times 10^6}=\cos i$, or $i=77°$.

These considerations are enough to show that we are nearly within reach of interesting *facts* relating to the evolution of stars. If telescopic observations show that *Capella* is a double star, we shall be in a position to deal with a known case of a star with a spectrum similar to that of the sun, though its mass and brightness may be very different. The complete investigation of the spectrum of the *Procyon* component is also likely to be of great interest in the same connexion.

I have great pleasure in taking this opportunity of saying that I owe much to the skill and care of my assistant, A. W. Goatcher. He has secured more than half of the photographs from which I have made the measurements contained in this note; and I am indebted to him in numberless ways for his unremitting patience and devotion.

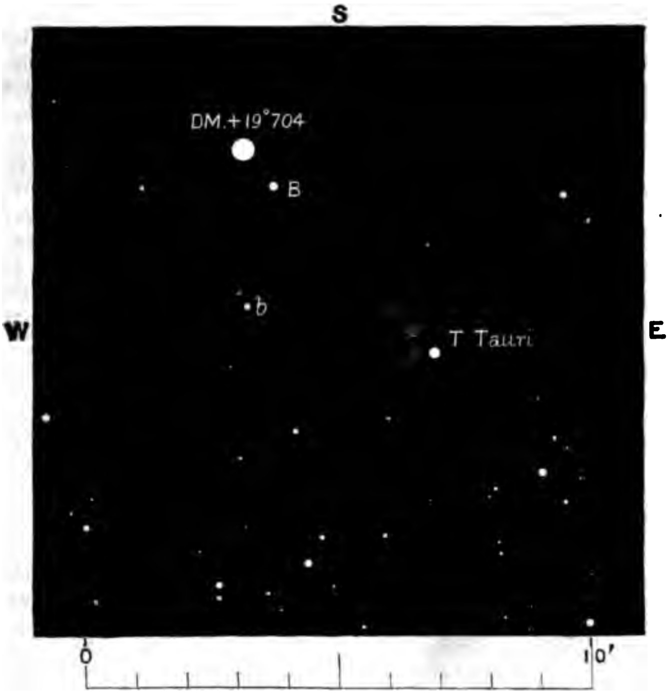
Note.—The best chance of detecting doubleness in *Capella* by visual observations through a large telescope will first occur about April 13, or say between April 3 and April 23. The approximate equality in brightness of the components shows that a dark glass may be used at the eye-end.

Photographic Observations of Hind's Variable Nebula in Taurus, made with the Crossley Reflector of the Lick Observatory. By James E. Keeler, D.Sc.

The region of *T Tauri* and Hind's variable nebula has frequently been scrutinised by observers with visual telescopes, but I have been unable to find any record of photographic observations. In making out an observing list for the Crossley Reflector, this region was therefore noted as specially requiring attention.

A complete history of previous observations of this region, ogether with original observations by himself and Mr. Burnham, as been given by Professor Barnard.* It will therefore be nnecessary for me to review the work of other investigators.

The first photograph with the Crossley Reflector was made n 1899 December 6, with an exposure of 3^h 53^m. It showed a light darkening of the film near *T Tauri*, which might have een an accidental stain. Accordingly, another photograph, rith four hours' exposure, was made on December 27, and it roved to be in exact agreement with the first. Both photographs are good, and the star discs are almost perfectly round, ut, for several reasons, they do not show as faint stars, by erhaps several magnitudes, as plates made with equal exposure-times during the fine nights of the previous summer.



Region of *T Tauri* and Hind's Variable Nebula.

From both negatives positives were made on glass with an nlargement of five diameters, and from one of these the accompanying diagram was copied, partly by tracing and partly by neasurement. It represents a field 12′ square. The diameters

* *Monthly Notices*, *R.A.S.*, vol. lv. p. 442.

of the photographic star discs (on the enlargement) are quite approximately reproduced, the largest stars being a little too large, and the smallest a little too small, though the latter are still more conspicuous than they are on the enlargement itself.

Hind's nebula, as shown on the photographs, is faint and very irregular. Three patches, of which the middle one is the brightest, and which are not sharply bounded on any side, are connected by still fainter nebulosity. They do not seem to be connected with *T Tauri*, though it is quite likely that a connection might be traced on a stronger photograph. From the sketches made by Professor Barnard and other observers, it appears that the brightest patch, or the two patches nearly in line with D.M. $+19°$ 704 are the parts of the nebula which have been observed visually.

The photograph shows no nebulosity whatever at the place of Struve's nebula.

At my request Mr. Aitken and Mr. Perrine examined this region with the 36-inch refractor on January 20 (a fine night). Hind's nebula was seen with difficulty, at the very limit of visibility, as were the faintest stars of the diagram. The magnitude of the latter may therefore lie between 16 and 17. The magnitude of the brighter star (*b*) at the place of Struve's nebula was estimated as 13; that of the smaller star as $15\frac{1}{2}$–16. The latter star was not seen by Professor Barnard, who says particularly that there was no star near *b*. The star is perhaps variable, or the conditions may have been more favourable on the night of Messrs. Aitken and Perrine's examination. Tempel's star near *b* does not agree in position with the star shown by the photograph.

On the night of January 20 both observers estimated that *T Tauri* was about half a magnitude fainter than the star *B* of the diagram. The photographic disc of *T Tauri* is, however, somewhat the larger. The photographic and visual magnitudes of these stars therefore do not agree, unless indeed there was a perceptible variation of the brightness of *T Tauri* between December 27, when the last photograph was taken, and January 20, when the visual observations were made.

Professor Barnard concludes from his investigation that Hind's nebula and Struve's nebula present incontestable cases of nebular variability, and it is likely that all astronomers agree with him. Indeed, it is inconceivable that the nebula near *T Tauri*, if no brighter than it is at present, could have been discovered with a small telescope. With respect to some of the details of the various observations of these nebulæ, which relate to objects at the very limit of vision, there is, I think, room for considerable doubt. So skilful an observer as Tempel has, as I have shown in an article which will be printed in another place,* drawn stars and nebulæ where none exist, while

* *The Astrophysical Journal* for January.

stars and nebulæ that certainly do exist escaped his notice. The fallibility of the observer must not be lost sight of.

Lick Observatory, University of California:
1900 *January.*

On a Simple Method of Comparing the Bonn Durchmusterung with Photographic Plates. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. The *Bonn Durchmusterung* gives R.A.s and Declinations for 1855·0. Measures of stars on a photographic plate give rectilinear coordinates (x, y) which are connected with standard coordinates (ξ, η) by linear relations

$$\xi = x + ax + by + c$$
$$\eta = y + dx + ey + f,$$

and (ξ, η) are connected with R.A. and Decl. for some other epoch (say 1900·0) by the relations

$$\xi = \tan(a - \mathrm{A}) \cos q \sec(q - \mathrm{D}) \qquad \eta = \tan(q - \mathrm{D}),$$

where $\tan q = \tan \delta \sec(a - \mathrm{A}),$

and (α, δ) are the R.A. and Decl. of the star,

(A, D) „ „ „ „ plate centre.

A circuitous method of comparing the B.D. with the plate is thus to perform the following operations :—

(1) Bring up the B.D. places to 1900·0.

(2) Convert into standard coordinates.

(3) Multiply by the plate constants a, b, c, &c., to get coordinates comparable with measures on the plate.

The present paper indicates a method of dispensing with operations (1) and (3), and generally performing the comparison very quickly.

2. The places of the *Durchmusterung* are given to $0^{s}\!\cdot\!1$ in R.A. and $0'\!\cdot\!1$ in Declination. In terms of a *réseau* interval of $5'$ (a unit now in common use for photographic measures) $0^{s}\!\cdot\!1$ on the equator represents 0·005, while $0'\!\cdot\!1$ represents 0·02. It will probably be sufficient accuracy in both coordinates if we calculate to 0·01 of a *réseau* interval, or in circular measure ·000015.

For the plates of the Astrographic Catalogue

x and y range from $-$·02 to $+$·02 in circular measure,

x^2 and y^2 „ „ 0 to ·0004,

x^3 and y^3 „ „ $-$·000008 to $+$ ·000008.

Hence we may neglect powers of the coordinates higher than the *second* for the present purpose; though it is quite easy to take account of these terms afterwards if so desired.

Now to the second order it will be found that

$$\xi=(\alpha-A)\cos\delta, \quad \eta=(\delta-D)+\tfrac{1}{4}(\alpha-A)^2\sin 2D.$$

3. The point of the present method lies in choosing the right value of A. If we increase A by A_0, we add to ξ and η the terms

$$-A_0\cos\delta, \quad -A_0(\alpha-A)\sin D\cos D+\tfrac{1}{4}A_0^2\sin 2D,$$

or if A_0 be of the same order as (ξ and η), since we can put $\cos\delta=\cos D-(\delta-D)\sin D$ to the first order, the terms to be added may be written

$$A_0\eta\sin D+\text{const.} \quad -A_0\xi\sin D+\text{const.}$$

which is equivalent to a rotation of the axes through an angle $A_0 \sin D$.

4. It is tolerably obvious, geometrically, that we can get the equivalence of a rotation of axes, or rather of the whole plate, by shifting the centre in R.A.; especially if we visualise the sphere as projected on a plane, say the tangent plane at the Pole. And the significance of the factor sin D is also clear from the geometrical standpoint: the rotation $A_0 \sin D$ vanishes at the equator whatever A_0 may be; in other words, the axes of η are all parallel for plates with centres on the equator—we cannot get this rotation there.

5. We proceed to use this principle to get an equivalent for precession. Bringing up the star places from 1855·0 to 1900·0 in the ordinary way is a rather complex numerical process. Viewed as the comparison of two plates of the same stars at different epochs, it merely means that one plate is rotated in its own plane with respect to the other, through a definite angle. To find this angle let us suppose two stars on the axis of η at 1900·0, so that $\xi=0$ for both; and let one be at the centre of the plate, the other Δ south of it, so that $\eta=0$ for the first and $\eta=-\Delta$ for the second. The problem is to choose A, the adopted R.A. of plate centre for 1855·0, so that the value of ξ for the two stars may be, not necessarily zero, but *the same* for both.

We can then reduce both values to zero by subtracting an appropriate constant for the plate, which is a simple matter.

6. If α be the common R.A. of the stars for 1900·0, the precessions for the two stars are

$$m+n\sin\alpha\tan D$$
$$m+n\sin\alpha\tan(D-\Delta).$$

[We are considering differential effects, and the secular variation, even for forty-five years, does not matter.]

Thus the R.A.s for 1855·0 will differ by

$$45n \sin \alpha \, [\tan D - \tan (D-\Delta)].$$

Write this $\beta \sin \Delta \tan D$,

where $\beta = 90n \sin \alpha \operatorname{cosec} 2D$.

Denote the R.A. of the central star for 1855·0 by A_1; that of the southern star by A_2; and that of the appropriate plate centre by A_3. Then we have to find A_3, so that

$$(A_2 - A_3) \cos (D-\Delta) = (A_1 - A_3) \cos D,$$

or

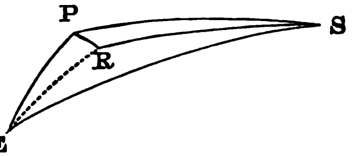
$$\begin{aligned} A_3[\cos D - \cos (D-\Delta)] &= A_1 \cos D - A_2 \cos (D-\Delta) \\ &= A_1[\cos D - \cos (D-\Delta)] \\ &\qquad + (A_1 - A_2) \cos (D-\Delta). \end{aligned}$$

Thus $$A_3 = A_1 + \beta$$

where from above the value of β is

$$\beta = 90n \sin \alpha \operatorname{cosec} 2D.$$

7. It will check this analytical result to look at the question geometrically.



Let E be the pole of the ecliptic,
P be the pole of the equator,
S a star, of coords. (α, D).

Precession carries P to R, in the direction perpendicular to EP, and towards the First Point of *Aries*.

Thus $\angle SPR = \alpha$.

Further $$\begin{aligned} PR &= 50''\!\cdot\!2 \sin \omega \times t \\ &= 45n, \text{ as in § 6.} \end{aligned}$$

Now PS and RS are the directions of the axis of y for the two plates, which are inclined to one another at

$$\begin{aligned} \angle PSR &= PR \sin \alpha \,.\, \operatorname{cosec} SP. \\ &= 45n \,.\, \sin \alpha \,.\, \sec D. \end{aligned}$$

We wish to correct this by choosing a plate centre differing in R.A. by the quantity β of the last paragraph. And by § 3 or

§ 4 the effect of this change of R.A. is to rotate the plate through an angle β sin D.

Hence $\beta \sin D = 45n \sin a \sec D$

or $\beta = 90n \sin a \operatorname{cosec} 2D$.

8. It may be a convenience to others to give here a table of the coefficients of sin a for different declinations, and the rule of signs.

Rule.—To form directly from the *Durchmusterung*, Epoch 1855·0, standard coordinates for 1900·0: if A_0 be the R.A. for 1855·0 of the actual plate centre, add to A_0 the quantity K sin A_0, where K is given in the following table in seconds of time:—

Dec.	K.	Dec.	K.	Dec.	K.
° °	min.	° °	s.	° °	s.
0 or 90	...	15 or 75	240	30 or 60	139
1 „ 89	(57)	16 „ 74	226	31 „ 59	136
2 „ 88	(29)	17 „ 73	214	32 „ 58	133
3 „ 87	(19)	18 „ 72	204	33 „ 57	131
4 „ 86	(14)	19 „ 71	194	34 „ 56	130
5 „ 85	(11)	20 „ 70	186	35 „ 55	128
6 „ 84	(10)	21 „ 69	179	36 „ 54	126
7 „ 83	(8)	22 „ 68	173	37 „ 53	125
	sec.				
8 „ 82	435	23 „ 67	167	38 „ 52	124
9 „ 81	388	24 „ 66	162	39 „ 51	123
10 „ 80	350	25 „ 65	157	40 „ 50	122
11 „ 79	320	26 „ 64	152	41 „ 49	121
12 „ 78	295	27 „ 63	149	42 „ 48	121
13 „ 77	274	28 „ 62	145	43 „ 47	120
14 „ 76	256	29 „ 61	141	44 „ 46	120
				45°	120

The method cannot be advantageously employed for plates near the equator or the poles.

Example.—To compare the B.D. with a plate taken with centre at $14^h\ 40^m$, $+37°$ at the Epoch 1900·0.

The R.A. of the plate centre for 1855·0 is $14^h\ 38^m\ 5^s$.

Take from above table the quantity for $+37°$, viz. 125^s. Multiply this by sin $14^h\ 40^m$, which is $-\sin 40°$ or $-·643$, getting -80^s or $-1^m\ 20^s$. Add this algebraically to $14^h\ 38^m\ 5^s$, getting $14^h\ 36^m\ 45^s = A'$ say.

If now (a, δ) be the coordinates of any star for 1855·0, and we form

$$\xi = (a - A') \cos \delta, \quad \eta = (\delta - 37°) + \tfrac{1}{4}(a - A')^2 \sin 74°$$

as in § 2 (where the angles are expressed in circular measure), then ξ and η only differ by a constant from standard coordinates for 1900·0.

9. We have hitherto supposed the plate correctly oriented for 1900·0. Any error of orientation may be corrected in the same way, by again altering the assumed R.A. of plate centre. If (x, y) denote measures on the plate, and (ξ, η) standard coordinates, an error of orientation is indicated by the relations

$$\xi = x - by$$
$$\eta = y + bx,$$

b being (in circular measure) the angle of rotation.

If this is compensated by a change A_3 in the plate centre, we must have by § 3 or § 4

$$\pm b \times 13751 = A_3 \sin D,$$

assuming that A_3 is expressed in seconds of time.

The following table indicates the value of A_3 for different values of b and different centres :—

Table showing how to compensate for the value of b by change of Adopted Plate Centre.

b	Dec. = 10° s	20° s	30° s	40° s	50° s	60° s	70° s	80° s	90° s
·001	79	40	28	21	18	16	15	14	14
·002	158	80	55	43	36	32	29	28	28
·003	238	121	82	64	54	48	44	42	41
·004	317	161	110	86	72	64	58	56	55
·005	396	201	138	107	90	80	73	70	69
·006	475	241	165	128	108	95	88	83	83
·007	554	281	193	150	126	111	102	97	97
·008	634	322	220	171	144	127	117	111	110
·009	713	362	248	193	162	143	131	125	124
·010	792	402	275	214	180	159	146	139	138

Rule of Signs.—If b denotes a rotation in the direction above indicated, so that

$$\xi = x - by, \quad \eta = y + bx,$$

(x, y) denoting measures, and (ξ, η) standard coordinates, then the adopted R.A. of the plate centre is to be *increased* by the above quantity before deriving (ξ, η); and we shall then get

$$\xi = x + \text{const.}, \quad \eta = y + \text{const.}$$

10. If the plate has a scale value different from that adopted

for (ξ, η), this can be allowed for in a variety of ways. Thus, in forming

$$\xi=(a-A)\cos\delta$$

if we wish to form instead

$$(1+p)\xi=(a-A)(1+p)\cos\delta,$$

we can do so indirectly by writing $(\delta+\epsilon)$ for δ, where

$$\cos(\delta+\epsilon)=(1+p)\cos\delta$$
$$\text{or } \epsilon=-p\cot\delta.$$

It must be remembered that great refinements are not necessary for the comparison of B.D. with our measures, and the mean scale value for a number of plates will probably be near enough for all, in spite of refraction and aberration. At Oxford the focal length of the instrument is nearly one per cent. too great, so that measures made with a standard *réseau* of 5^{mm} spaces have all to be diminished in the ratio 1·0078 to 1. Recently, this troublesome correction (which ought to have been avoided by greater care on the part of the maker of the object-glass) has been obviated by measuring with a *réseau* of $5^{mm}\cdot04$ spaces, so that the scale value is now approximately correct. Suppose then that we have made tables for the more recent plates, as below.

Table for $(a-A)\cos\delta$ in Réseau intervals.

(a − A) m s	Dec′ = 25° 0′	10′	20′	30′	40′	50′	26° 0′
0 10	0·453	0·453	0·452	0·451	0·451	0·450	0·449
20	0·906	0·905	0·904	0·903	0·901	0·900	0·899
30	1·360	1·358	1·356	1·354	1·352	1·350	1·348
40	1·813	1·810	1·853	1·850	1·848	1·845	1·843
50	2·266	2·263	2·259	2·257	2·254	2·250	2·247
1 0	2·719	2·716	2·711	2·708	2·704	2·700	2·696
10	3·172	3·168	3·163	3·159	3·155	3·150	3·146
20	3·626	3·621	3·615	3·610	3·606	3·600	3·595
&c.	&c.		&c.				

the equivalent of the seconds and tenths being found from a supplementary table, and added to the number taken from above before contracting to two figures.

To use this table for comparing the B.D. with measures on

the old plates with defective scale value, we need only substitute for the headings,

	25° 0′,	25° 10′,	25° 20′,	25° 30′,	25° 40′, &c.
the values	25° 56′,	26° 6′,	26° 15′,	26° 25′,	26° 34′, &c.

and the tables are then adapted to the old plates.

For the formation of $\eta=(\delta-D)+\frac{1}{4}(\alpha-A)^2 \sin 2D$, the second term will not generally need correction, and the first term can be multiplied by the proper factor by means of a small table.

The Use of a Coloured Screen in Photographing the Corona during an Eclipse. By W. Shackleton, A.R.C.Sc.

It has long been known that the distribution of *coronium* throughout the corona was not concurrent with the streamers themselves, the '1474 K' line often being as strong in rifts as elsewhere. From observations made at the eclipse of 1898 both Mr. Newall and Mr. Fowler pointed out that the image of the corona, viewed in the monochromatic light of the green corona line, had decided variations from that seen or photographed directly. In the main the image of the former corresponds to an *inner corona*; this *inner corona* not being merely a sort of under-exposed picture of the whole, but one having a delineation of its own which does not agree with the corona proper. If, then, it were possible to photograph the corona in '1474 K' light alone, we should determine the distribution of *coronium* throughout the corona.

The most obvious way of photographing the corona in the light of the green corona line would be, of course, to use some spectroscopic method; but I wished rather to employ simple apparatus, and from the following considerations I think it possible this may be done by the use of a camera provided with a suitably coloured screen. It will be seen, on examining the photographs taken with prismatic cameras or other spectroscopes during the eclipses of 1893, 1896, and 1898,* that the light of the corona consists principally of continuous spectrum, the line spectrum, with the exception of '1474 K,' being feeble. This line, however, is strong enough to give good decided impressions, although falling in a region of weakness on the isochromatic plates used; indeed, it is so intense that I have seen it recorded on plates supposed to be insensitive to the green.

Referring again to the above photographs, it appears that the continuous spectrum has been photographed to a greater distance from the Sun's limb than has the line spectrum.

* *Phil. Trans.*, A, vol. clxxxvii. (1896), Plates 11, 12; vol. clxxxix. (1897), Plate 9. *Monthly Notices*, R.A.S., vol. lviii., Appendix, Plate 9.

A photograph of the corona on an isochromatic plate sensitive to the rays from yellow to violet, then, is built up of light represented by the continuous spectrum between λ 5900 and λ 3800, together with the light of the line spectrum, represented chiefly by the lines λ 5303 ('1474 K'), λ 4231, λ 3987, the two latter being weak in comparison with the former.

Supposing, therefore, by the use of an absorbing medium we could limit the spectrum to within a short distance on either side of '1474 K,' say by the use of the coloured screen described below, something like 90 to 95 per cent. of the continuous spectrum would be cut off, whilst only a small percentage of line giving light would be absorbed.

Hence by taking a photograph through such a screen we should have the two images, one from the continuous spectrum between λ 5320 and λ 5200, the other from '1474 K' light superposed.

But from the fact that the '1474 K' line is so very intense, and also that the image in this light is of less extent than the ordinary coronal image, it appears very probable that the corona thus photographed would be chiefly due to the *coronium* radiations; the image from the continuous spectrum being relatively weak and spread over a large area, would consequently be too feeble to register in an eclipse of moderately short duration.

From experiments I have made I found it difficult to procure a simple green, but by using two screens stained with the aniline dyes, methylene blue and tartrazine respectively, a resulting colour is produced which allows a narrow band of green light to filter through, the yellow, blue, and violet rays being suppressed. The position of the green line from the corona falls within this band.

The following table shows where the absorption takes place in each case :—

Absorbing Medium.	Edge of Absorption Band. λλ	Rays Absorbed.
Tartrazine—		
(1) Light stain	5100	Green, and more refrangible.
(2) Deep „	5290	„ „ „
Methylene blue—		
Medium stain	5320	Yellow, and less refrangible.

It is necessary to use a yellow screen of moderate depth of tint to insure the blue light being well cut off, therefore we may say that the band of green light which is unabsorbed extends from λ 5200 to λ 5320. This being the case, only about 6 per cent. of the light-giving continuous spectrum could pass through, whilst practically all the light of the green corona line would be unopposed.

No doubt some of the green commercial screens used in three-colour photography would be found suitable, but so far I have not tested any of these.

I am indebted to Dr. Morgan, of the Royal College of Science, for samples of various dyes.

NOTE.—Since the above was communicated to the Society Professor Langley, in a letter to *Nature*,* describes the great intensity of the inner corona, and how in consequence of this brilliance he was able to see *Mercury* in transit projected on the bright background, before it reached the Sun's limb. During the eclipse of 1878 he made a brief telescopic examination of the inner corona, and found it to be "a surprisingly definite filamentary structure . . . . not disposed radially, or only so in the rudest sense, sharpest and much the brightest close to the disc, fading rapidly away into invisibility at a distance of 5′ or more (possibly in some cases ten)."

This description of the inner corona agrees well, in respect to extension, brightness, and non-coincidence of the ordinary radial streamers, with the image of the corona seen in the light of the green coronal line.

Professor Langley further says "that while most interesting photographs of the inner coronal structure have recently been made, yet that this feature has not yet been done justice to even in the best of them I have seen, and that it perhaps cannot be, with our present means."

It would be interesting to see if by the use of a coloured screen this structural detail could be brought out more distinctly.

In a lecture delivered at the Society of Arts, 1900 March 12, on the "Photography of Colour," Mr. E. Sanger Shepherd states that he rejects liquid solutions and stained glass as unsuitable for colour filters, and pronounces in favour of aniline dyes sealed up in gelatine or collodin, between glasses; by experiment a number of these dyes have been found to be of fair permanency.

The Maximum Duration Possible for a Total Solar Eclipse. By C. T. Whitmell, M.A., President of the Leeds Astronomical Society.

Total solar eclipses are among the grandest of natural phenomena. Prolonged totality is very uncommon, and its rarity invests it with exceptional interest.

The eclipse of Thales on 585 B.C. May 28, and that visible in Scotland on 1433 A.D. June 17, were remarkable for prolonged totality.

To come to more recent times, the eclipse of 1868 August 17 is said to have exceeded both those just referred to.

By the kindness of Dr. Downing an estimate of the duration of totality of this 1868 eclipse has been made, and—for local

* Vol. lxi. p. 443, 1900 March 8.

noon—the result is $6^m\ 49^s$. I have obtained a similar result. Governor Hennessy observed this eclipse from Barram Point, Borneo, where, in the afternoon, totality lasted $6^m\ 13^s$; and this is, I believe, the longest duration as yet actually observed.

Noon totality occurred in the Gulf of Siam, at E. longitude 102° 38′ and N. latitude 10° 27′. The conditions were very favourable, the Sun being not very far from apogee, the Moon near a favourable perigee, and almost in the zenith; whilst the observer, being in a low latitude, was situated on a rapidly moving part of the Earth.

The corresponding eclipse of the preceding *Saros* occurred on 1850 August 7. Mr. Paine (see *Monthly Notices, R.A.S.*, vol. xxix.) estimates the noon totality at $6^m\ 51^s$. It would be well to check this result, using the present eclipse values of the diameters of the Sun and Moon.

The eclipse of 1886 August 28 in the *Saros*, subsequent to 1868, had a totality of $6^m\ 35^s$, according to the *Nautical Almanac*. For the eclipse on 1901 May 17, the same authority gives a totality of $6^m\ 30^s$ for a place at which the occurrence of totality will be almost at local noon.

The two series of eclipses, 1850, 1868, 1886, &c., and 1883, 1901, 1919, &c., are amongst the most favourable in the whole history of astronomy.

Mr. Crommelin has kindly furnished me with the following results, calculated by him from Oppolzer's data:—

Date.	Duration at Noon.	Position of Noon Point. Longitude.	Position of Noon Point. Latitude.
	m s	°	°
1901 May 18	6 41·6	97 E.	2 S.
1919 May 29	7 6·9	18 W.	4 N.
1937 June 8	7 19·9	131 W.	10 N.
1955 June 20	7 24·5	117 E.	15 N.
1973 June 30	7 19·6	6 E.	19 N.
1991 July 11	7 10·7	105 W.	22 N.

The 1955 noon eclipse will occur not far from Manila, and its totality is the longest for many centuries.

Mr. Crommelin states that the above durations are trustworthy only to the nearest second, and that Oppolzer's data yield durations about eleven seconds in excess of those of the *Nautical Almanac*, which (I may add) are themselves probably some three seconds in excess of the results of observation.

I now proceed to consider the conditions necessary for the longest totality.

For simplicity, suppose at first that the Moon and the Sun move in the plane of the Earth's equator. When the centres of the three bodies are in a line, the Moon being between the Sun and the Earth, there will be a central solar eclipse at local noon. Suppose this to be total. Bring the Moon nearer to the Earth, and the size of her shadow, or umbra, will increase. Her

elocity also will increase. But the former factor far more than ompensates for the latter, so that totality is lengthened by ringing the Moon nearer.

This may seem obvious, but I find that, if the Moon moved in *circular* orbit, the increased velocity, when her distance was ess than 104,000 miles, would more than compensate for the arger umbra, and the duration of totality would therefore fall ff, if the Moon, moving in a circular orbit, had a radius vector f less than 104,000 miles.

Now take the Sun further away. The umbra again becomes arger, and the Sun's velocity diminishes. This latter result is a rawback, but is far more than compensated for by the increased ize of the umbra. Thus, for a prolonged totality, the Moon hould be as near, and the Sun as far off, as possible. The dura-ion of totality increases with the size of the umbra, but iminishes with its velocity over the observer. Now, in the ase supposed, the velocities of the Sun, the Moon, and the bserver on the equator, are all in the same direction, *i.e.* from est to east, and, at local noon, are all perpendicular to the lane of the observer's meridian.

Thus the linear velocity of the umbra over the observer will e equal to that of the Moon, less that of the Sun in relation to he Moon, less that of the observer. We see, then, that so far as elocity is concerned it is better to have the Sun near and the Moon far away; but, as already explained, the increased size of the mbra (due to the nearness of the Moon and to the distance of the Sun) far more than compensates for its increased velocity.

Take the Earth's equatorial radius as 3963 miles, then, at nean distance, the linear sidereal velocity of the Moon is about 2288 miles an hour; but her linear synodical velocity in relation o the Sun is only 2117 miles per hour. The observer's velocity n the equator is 1037·5 miles per hour. Thus we get 1079·5 niles per hour as the noon velocity of the umbra over the bserver. During the brief duration of even the longest totality he directions and values of these velocities will remain practically nchanged.

As a matter of fact, for mean distances of the Sun and Moon there would be no total eclipse, but the velocity values given above may be of interest.

There are really five conditions required for maximum otality.

1. The new Moon, at or very near a node, must be at the nost favourable perigee possible.

2. The Sun must be at apogee.

3. During totality, which should be observed at local noon, he Moon's shadow must run along a parallel of latitude in order hat the diurnal movement of the observer may be for the time arallel to the motion of the Moon, and thus produce its full ffect in detaining him within the umbra.

4. The Sun and Moon must be in the zenith, so that the mbra may be as large as possible.

5. The observer must be on the equator, so that his velocity may be as great as possible.

The foregoing conditions could all be simultaneously fulfilled if the Sun and Moon moved in the plane of the equator; but, as this is not the case, we have to make a compromise consistent with the actual facts of nature.

We must keep conditions (1) and (2). Now it is a curious and fortunate thing that condition (3) can then also be fulfilled. The Moon's orbit makes an angle of about 5° with the ecliptic, and this is also about the value of the angle made by the descending ecliptic with that parallel of latitude which cuts it at its apogee point. The Moon must, of course, be in her ascending node, or very near it.

In other words, the Moon's declination, under the given conditions, will be at its monthly maximum, and so will scarcely vary during totality.

It is obvious, however, that conditions (4) and (5) cannot be satisfied simultaneously. Condition (4) puts the observer near the Tropic of Cancer. This increases the umbra, but lessens the observer's velocity. Condition (5) puts him on the equator. This increases his velocity, but diminishes the umbra, for the Moon is no longer in the zenith. We shall find that neither of these positions is the best possible, though (5) is more favourable than (4).

Suppose the Sun at apogee; what perigee distance can the Moon then have, consistently with her being new and at her node? For valuable help in determining this point I am indebted to Mr. Cowell, of Greenwich Observatory; but he is in no way responsible for my numerical results. Using Delaunay's "Lunar Theory," I compute that the Moon's horizontal parallax, under the above conditions, amounts to 61′ 22″. I shall be very glad to have this result confirmed. Under other conditions, such as the Moon being full, or 90° from her node, or the Sun being at perigee, the Moon's parallax may be greater, but these conditions are inconsistent with the problem under consideration.

Suppose the Earth to be a sphere, radius 3963 miles. Put the Sun at apogee, in N. declination 22° 53′ 55″, with an angular semi-diameter of 15′ 43″·78, this being calculated from the reduced mean distance semi-diameter, 15′ 59″·63, used for eclipses. Let the new Moon be at perigee, and at her node, with a parallax of 61′ 22″. The linear semi-diameter of the Moon is about 1081·5 miles, and her geocentric angular semi-diameter is 16′ 44″·77, if we use 15′ 34″ for the semi-diameter at mean distance, and not the smaller "eclipse" value.

Let the observer's geocentric latitude (ϕ) be 22° 53′ 55″ N., and let the Moon be at her node and in the zenith at local noon. The observer's velocity will be less than at the equator, being only 955·74 miles an hour. The Moon's synodic velocity is 2310·50 miles per hour. The diameter of the umbra is 167·89 miles, and its velocity over the observer will be 1354·76 miles

per hour. Putting T for the duration of totality in hours, we obtain for the duration at noon,

$$\text{N. latitude } \phi = 22^\circ\ 53'\ 55'',\ T = \frac{167 \cdot 89}{1354 \cdot 76} = 7^m\ 26^s \cdot 13 \quad . \quad A$$

In the case just considered the Moon was in the zenith. Now suppose her to have a small geocentric south latitude, so that her shadow falls on the equator. The umbra will be smaller, as the Moon is no longer in the zenith, but the observer's velocity will be greater, so that the velocity of the umbra in relation to the observer is diminished also:

$$\text{Latitude } \phi = 0^\circ\ 0'\ 0'',\ T = \frac{165 \cdot 08}{1273 \cdot 00} = 7^m\ 46^s \cdot 84 \quad . \quad . \quad B$$

distinctly exceeding (A).

Will this be the maximum totality? To determine this I formed an equation for T, and in this equation the latitude (ϕ) of the observer was practically the only independent variable. Differentiating this, and equating to zero in the usual way, T should be a maximum when $\phi = 4^\circ\ 47'\ 13''$ N. Using this value, we get

$$\text{N. latitude, } \phi = 4^\circ\ 47'\ 13'',\ T = \frac{166 \cdot 12}{1276 \cdot 62} = 7^m\ 48^s \cdot 45 \quad . \quad C$$

This exceeds (B) by $1^s \cdot 61$, and is really the maximum under the given conditions. T diminishes for latitudes either N. or S. of this value of ϕ. About N. latitude 9° or 10° T again becomes equal to its value for the equator.

We notice in (B), (C), (A) that the breadth of the umbra and its velocity are both increasing, but at different rates, and that their ratio becomes a maximum in case (C).

But the equation for the latitude has two roots, and the second value of ϕ is $192^\circ\ 32'\ 47''$. This means that we must put the observer in S. latitude $12^\circ\ 32'\ 47''$, and in longitude 180° away from his former position. We must also suppose the Earth transparent, so that the shadow can pass through to the side of it away from the Sun. Granting these suppositions, there will be a central total solar eclipse at local midnight.

$$\text{S. latitude, } \phi = 12^\circ\ 32'\ 47'',\ T = \frac{95 \cdot 97}{3323 \cdot 23} = 1^m\ 43^s \cdot 96 \quad . \quad D$$

This corresponds to *minimum* duration under the given conditions. The umbra, owing to the observer's increased distance, is much smaller, and its velocity is much greater, for now the observer's velocity has to be added to the synodical velocity of the Moon, for the observer is now moving in a direction opposite to that of the shadow.

This result is only of theoretical interest, but it well illustrates the generality of a mathematical formula, which disdains to take into account such a trifle as the Earth's opacity.

In an actual eclipse of the midnight Sun, the duration of totality is similarly shortened by the increased distance of the observer from the Moon, and by the condition that his velocity has to be added to that of the umbra.

To the foregoing results the following objections may be raised: that the Moon's radius has been taken too large, that the Earth's radius varies with the latitude, and that 3963·296 miles is a more accurate value of the equatorial radius. I have therefore re-calculated the results, using for the Moon's angular semi-diameter at mean distance the "eclipse" value $15' \; 32''{\cdot}65$, given in the *Nautical Almanac*. This corresponds to a radius of about 1080 miles, if we take 3963·296 miles for the Earth's equatorial radius, and reckon the Moon's horizontal parallax at mean distance to be $57' \; 2''{\cdot}70$. I have also allowed for the variation of the Earth's radius with the observer's latitude. The durations are now as follows:—

Equator, $\phi=0° \; 0' \; 0''$, $T=\frac{161{\cdot}93}{1272{\cdot}99}=7^m \; 37^s{\cdot}94$. E

N. latitude, $\phi=4° \; 0' \; 0''$, $T=\frac{162{\cdot}82}{1275{\cdot}53}=7^m \; 39^s{\cdot}54$. F

N. latitude, $\phi=4° \; 51' \; 45''$, $T=\frac{162{\cdot}99}{1276{\cdot}75}=7^m \; 39^s{\cdot}58$. G

N. latitude, $\phi=6° \; 0' \; 0''$, $T=\frac{163{\cdot}20}{1278{\cdot}71}=7^m \; 39^s{\cdot}46$. H

The latitude for the maximum eclipse (G) is now a little ($4' \; 32''$) higher than before (C), and the duration is about 9 seconds less, a reduction due almost entirely to the Moon's smaller diameter of 2160 miles. But it will be noticed that the excess of duration of (G) over (E) is $1^s{\cdot}64$, about the same as it was in the case of (C) and (B). Of course, I assume not complete, but only relative, accuracy for the figures given. But I hope that, with the data used, there is no serious error in the results. For parallax $61'22''$ the Moon's semi-diameter is $16'43''{\cdot}30$.

The conclusion, then, is that, with the accepted present eclipse values of the diameters of the Sun and Moon, and with a lunar parallax of $61' \; 22''$, the maximum eclipse totality will occur near the beginning of July, at noon, in geocentric N. latitude about $4° \; 52'$, and will last about $7^m \; 40^s$, the Sun being at apogee with a parallax of $8''{\cdot}70$. The Sun's and Moon's declinations are considered to be practically constant during totality.

If it were possible for the Sun and Moon to be in the plane of the equator, so that the Moon could be in the zenith, the eclipse would last $7^m \; 45^s{\cdot}88$, and the maximum would then be really on the equator. This, however, is impossible.

Mr. G. F. Chambers, in his comprehensive *Handbook of Astronomy* (vol. i. p. 268) quotes from Du Séjour a statement to the effect that maximum totality occurs on the equator, and lasts $7^m \; 58^s$. This statement has been copied into numerous text-

books. I have consulted the original paper in *Mémoires de l'Académie Royale des Sciences*, Paris, 1777, p. 318. Du Séjour states that the longest totality will occur at noon on the equator on July 2, with the Sun at apogee. The following data are used by him. Sun's semi-diameter, 15′ 42″; hourly motion in the ecliptic, 2′ 23″; declination, 22° 50′ N. The Moon is near her ascending node, in S. latitude 23′ 57″; hourly motion, reduced to the ecliptic, 38′ 16″; greatest polar parallax, 61′ 17″.

He does not give the Moon's semi-diameter, nor the relation between the polar and the equatorial radius of the Earth. With the ratio at present accepted, a polar parallax of 61′ 17″ would yield an equatorial one of 61′ 29″. He does not refer to the conditions which (I presume) were imposed upon the Moon's parallax by the lunar theory of his time, nor does he appear to be aware that the maximum totality is not actually on the equator. Taking Du Séjour's elements, and assuming for the Moon an equatorial parallax of 61′ 29″, and using her smaller semi-diameter, I get a result practically agreeing with his for an eclipse on the equator. But it seems to me that the parallax is larger than the lunar theory will permit under the conditions, and also that the semi-diameter of the Sun is too small.

Lord Grimthorpe, in his *Astronomy without Mathematics*, writes (p. 151) that "under a combination of the most favourable conditions totality may last something more than 7 minutes." But he bases his calculation upon an umbra only 148 miles in diameter, and this is decidedly under the mark. He also assumes the perigee distance of the Moon to be 221,600 miles, and this corresponds to a parallax of about 61′ 29″. If my computations are correct, this parallax, like that used by Du Séjour, exceeds the value allowed by the lunar theory under the given conditions. In addition to contributing interesting data as to future eclipses, Mr. Crommelin has been good enough to read over the MS. of this paper.

Leeds: 1900 *February*.

Observations of Saturn made at Juvisy Observatory in 1899. By C. Flammarion.

Observations of *Saturn* were commenced here during the last apparition on 1899 June 1, and continued till July 30. The number of fine nights was abnormally great, a circumstance which more than compensated for the low altitude of the planet above the southern horizon.

The instrument employed was the Juvisy 10¼-inch equatorial, bearing powers of 224, 308, 411 and 617, and the observations were made by M. Antoniadi and myself.

1. *The Globe.*

The N. polar cap was not particularly dark in 1899, appearing certainly lighter than it did in 1895. No trace of the N. temperate band; but the double N. tropical belt was an obvious feature under almost every kind of definition.

The dark spots which sprinkle this belt, and especially its S. component, were missed here in 1899, though vague traces of some seem to have been caught on July 7 and 27.

Also, the equatorial zone did not show its ordinary "wool pack" structure, while the narrow equatorial belt was invisible.

An interesting "black drop" appearance, due to irradiation, was repeatedly detected in the shadow cast by the planet on the ring, there where it met the Cassini division.

2. *The Rings.*

(*a*) *Outer Ring, A.*—Encke's division was seen on one occasion only, on July 30, the best night of the season (Plate 12), when it was perfectly visible on both ansæ. An easier feature of Ring A was a series of dusky indentations emerging from the Cassini division. The outer edge of A was in no wise sharply defined, but seemed to shade off rather gently into space.

Cassini's division could be traced all round the Ring without difficulty, even under very poor seeing. It was not black, but dark grey. The division seemed tangent to *Saturn's* N. limb.

(*b*) *Inner Bright Ring, B.*—This Ring shaded into the "Crape" Ring without any intermediate separation. On July 30 B was split into two rings by the certain visibility, on both ansæ, of a narrow and faint dusky line as shown in the Plate.

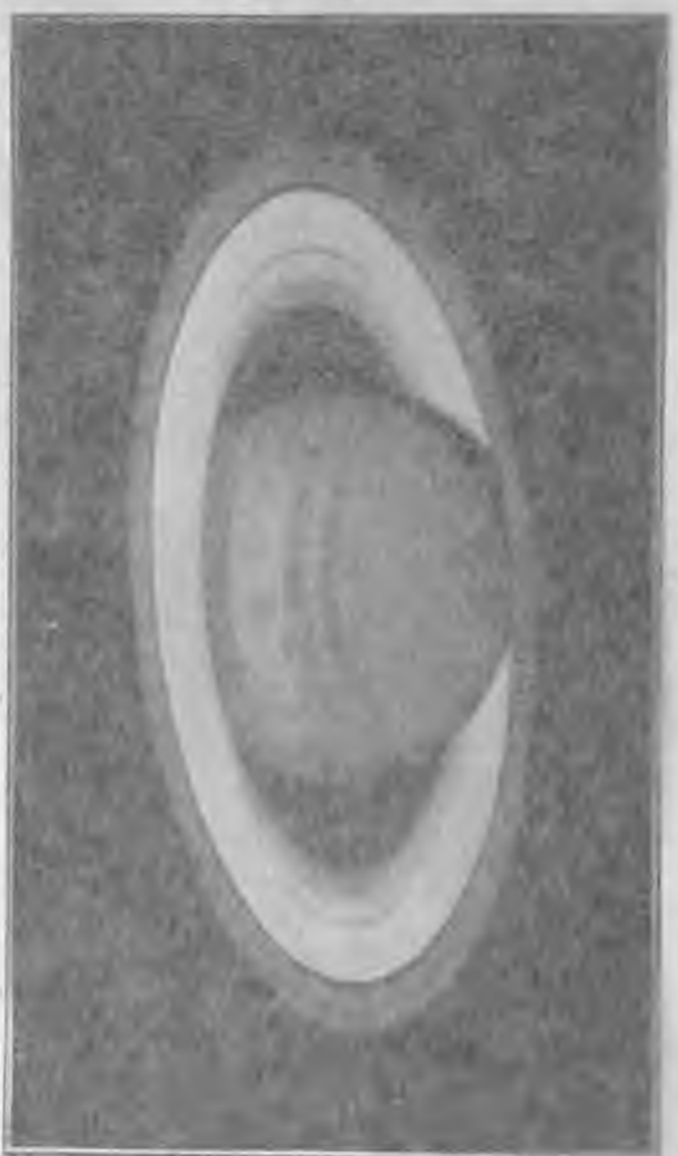
(*c*) *The "Crape" Ring, C*, showed nothing abnormal, excepting, perhaps, an exaggerated concavity of its inner outline towards the centre, due probably to the interference of the S. equatorial belt of *Saturn.*

The eccentricity of the Ring, noted here every year since 1895, was re-observed in 1899. The eastern vicinity was still larger than the western, though the difference was certainly less marked than a few years ago.

Juvisy Observatory (S.-et-O.), France,
1899 *December* 30.

Note on a Possible Occultation of A Geminorum by Venus, 1900 *May* 27–28. By Walter W. Bryant.

At about $2^h\ 45^m$ A.M. May 28, Greenwich civil time (some hours before the eclipse), *Venus* will be in conjunction in R.A. with *A Geminorum*, a star of the fifth magnitude, whose place for the day is approximately $7^h\ 17^m\ 24^s{\cdot}5$, N. $25°\ 14'\ 30''$. The



1. *The Globe.*

The N. [illegible] was not particularly dark in 1899, appearing [illegible] than it did in 1895. No trace of the N. [illegible], but the double N. tropical belt was an obvious [illegible] every kind of definition.

[illegible] sprinkle this belt, and especially the S. [illegible] here in 1899, though vague traces of [illegible] caught on July 7 and 27.

[illegible] zone did not show its ordinary "wool [illegible]," while the narrow equatorial belt was invisible.

An [illegible] "black drop" appearance, due to irradiation, was [illegible] in the shadow cast by the planet on the ring, [illegible] the Cassini division.

2. *The Rings.*

(a) *Outer Ring, A.*—Encke's division was seen on [illegible] July 30, the best night of the season (Plate [illegible]), [illegible] perfectly visible on both ansæ. An [illegible] of Ring A was a series of dusky indentations emerging from the [illegible] division. The outer edge of A was in no wise [illegible], but seemed to shade off rather gently into space.

[illegible] could be traced all round the Ring without difficulty, even under very poor seeing. It was not black, but dark grey. The division seemed tangent to *Saturn's* N. limb.

(b) *[illegible] Ring, B.*—This Ring shaded into the "Crape" Ring without any intermediate separation. On July 30 B was split into two rings by the certain visibility, on both ansæ, of a narrow and faint dusky line as shown in the Plate.

(c) *The "Crape" Ring, C*, showed nothing abnormal, excepting [illegible] exaggerated concavity of its inner outline [illegible] centre, due probably to the interference of the S. [illegible] *Saturn.*

[illegible] of the Ring, noted here every year since [illegible] in 1899. The eastern vicinity was still [illegible] western, though the difference was certainly less [illegible] years ago.

[illegible] (S.-et-O.), France,
[illegible] 20.

Note on a possible Occultation of A Geminorum by *Venus*, [illegible] By Walter W. Bryant.

At [illegible] May 20, Greenwich civil time (some hours before the [illegible] *Venus* will be in conjunction in R.A. with *A Geminorum*, [illegible] of the fifth magnitude, whose place for the day [illegible] approximately [illegible] $17^{m}\ 24^{s}\cdot5$, N. $25^{\circ}\ 14'\ 30''$. The

MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY. VOL. LX., PLATE 12.

E

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SATURN

AS SEEN AT M. FLAMMARION'S OBSERVATORY ON 1899, JULY 30

BY E. M. ANTONIADI.

distance of the star from the limb of *Venus* amounts to about 9″, or half the horizontal parallax, *Venus* being south of the star.

It is practically certain that for a great part of the South Pacific the star will be occulted by *Venus* after sunset; and at some of the antipodean observatories, though there the Sun will not have set, there may be a good chance of obtaining observations of the phenomenon.

Ephemeris for Physical Observations of the Moon for the Second Half of 1900. By A. C. D. Crommelin.

Greenwich Midnight. 1900.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
		°	°	°	°	°	°
July	1	325·64	−0·72	+1·54	+6·74	6·91	347·1
	2	337·87	−0·75	+0·34	+6·69	6·70	357·1
	3	350·11	−0·77	−0·92	+6·35	6·42	8·2
	4	2·33	−0·79	−2·20	+5·73	6·14	21·0
	5	14·55	−0·81	−3·39	+4·87	5·93	34·8
	6	26·77	−0·84	−4·45	+3·77	5·83	49·7
	7	38·98	−0·86	−5·26	+2·48	5·82	64·8
	8	51·18	−0·88	−5·78	+1·04	5·87	79·8
	9	63·37	−0·91	−5·95	−0·48	5·97	94·6
	10	75·57	−0·94	−5·72	−2·03	6·07	109·5
	11	87·76	−0·96	−5·11	−3·49	6·19	124·3
	12	99·95	−0·98	−4·14	−4·78	6·32	139·1
	13	112·14	−1·01	−2·88	−5·78	6·46	153·5
	14	124·33	−1·03	−1·45	−6·42	6·58	167·3
	15	136·52	−1·05	+0·04	−6·64	6·64	180·3
	16	148·73	−1·07	+1·47	−6·44	6·61	192·9
	17	160·93	−1·09	+2·74	−5·82	6·43	205·2
	18	173·14	−1·10	+3·78	−4·85	6·15	217·9
	19	185·36	−1·12	+4·58	−3·60	5·83	231·8
	20	197·59	−1·13	+5·11	−2·16	5·55	247·1
	21	209·83	−1·15	+5·40	−0·63	5·42	263·3
	22	222·07	−1·16	+5·46	+0·91	5·54	279·5
	23	234·32	−1·18	+5·32	+2·38	5·83	294·1
	24	246·57	−1·19	+4·97	+3·71	6·20	306·7
	25	258·82	−1·20	+4·50	+4·83	6·60	317·0
	26	271·07	−1·22	+3·82	+5·70	6·86	326·2
	27	283·32	−1·23	+2·98	+6·29	6·96	334·7
	28	295·57	−1·24	+1·99	+6·59	6·88	343·2

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1900.	°	°	°	°	°	°
July 29	307·81	−1·26	+0·85	+6·59	6·64	352·7
30	320·05	−1·27	−0·39	+6·31	6·32	3·5
31	332·29	−1·28	−1·70	+5·75	6·00	16·5
Aug. 1	344·52	−1·30	−3·01	+4·95	5·79	31·3
2	356·74	−1·31	−4·26	+3·94	5·80	47·2
3	8·96	−1·33	−5·36	+2·73	6·01	63·0
4	21·18	−1·34	−6·22	+1·37	6·36	77·6
5	33·38	−1·36	−6·76	−0·08	6·76	90·7
6	45·58	−1·37	−6·90	−1·48	7·06	102·1
7	57·78	−1·39	−6·58	−3·03	7·24	114·7
8	69·97	−1·40	−5·78	−4·35	7·23	127·0
9	82·15	−1·41	−4·53	−5·43	7·07	140·2
10	94·33	−1·42	−2·91	−6·18	6·83	154·8
11	106·51	−1·43	−1·07	−6·52	6·61	170·7
12	118·69	−1·44	+0·83	−6·40	6·45	187·4
13	130·87	−1·45	+2·62	−5·85	6·41	204·1
14	143·06	−1·45	+4·16	−4·92	6·44	220·2
15	155·26	−1·46	+5·36	−3·69	6·51	235·5
16	167·47	−1·46	+6·18	−2·26	6·58	249·9
17	179·68	−1·47	+6·62	−0·74	6·66	263·6
18	191·90	−1·47	+6·74	+0·80	6·79	276·8
19	204·13	−1·47	+6·56	+2·25	6·94	288·9
20	216·36	−1·47	+6·16	+3·56	7·12	300·0
21	228·59	−1·47	+5·56	+4·68	7·27	310·1
22	240·83	−1·47	+4·79	+5·56	7·34	319·3
23	253·07	−1·48	+3·90	+6·17	7·30	327·7
24	265·31	−1·48	+2·88	+6·49	7·10	336·1
25	277·55	−1·48	+1·76	+6·52	6·75	344·9
26	289·79	−1·48	+0·54	+6·27	6·29	355·1
27	302·02	−1·49	−0·76	+5·74	5·79	7·5
28	314·25	−1·49	−2·11	+4·97	5·40	23·0
29	326·48	−1·49	−3·45	+3·99	5·27	40·8
30	338·71	−1·49	−4·73	+2·82	5·51	59·2
31	350·93	−1·49	−5·87	+1·52	6·06	75·5
Sept. 1	3·14	−1·50	−6·79	+0·12	6·79	89·0
2	15·35	−1·50	−7·30	−1·32	7·42	100·3
3	27·54	−1·50	−7·50	−2·74	7·98	110·1
4	39·74	−1·50	−7·32	−4·05	8·37	119·0

Greenwich Midnight.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1900.		°	°	°	°	°	°
Sept.	5	51·92	−1·50	−6·53	−5·17	8·33	128·4
	6	64·10	−1·50	−5·23	−6·00	7·96	138·9
	7	76·27	−1·49	−3·49	−6·45	7·33	151·6
	8	88·44	−1·49	−1·45	−6·46	6·62	167·3
	9	100·61	−1·48	+0·70	−6·01	6·05	186·6
	10	112·77	−1·47	+2·77	−5·13	5·83	208·4
	11	124·94	−1·47	+4·59	−3·91	6·03	229·6
	12	137·12	−1·46	+6·02	−2·45	6·50	247·9
	13	149·31	−1·45	+7·00	−0·88	7·06	262·8
	14	161·49	−1·44	+7·54	+0·70	7·57	275·3
	15	173·69	−1·43	+7·66	+2·19	7·97	286·0
	16	185·90	−1·41	+7·43	+3·54	8·23	295·5
	17	198·10	−1·40	+6·90	+4·67	8·33	304·1
	18	210·32	−1·39	+6·15	+5·56	8·29	312·1
	19	222·53	−1·38	+5·22	+6·18	8·09	319·8
	20	234·76	−1·37	+4·16	+6·52	7·72	327·5
	21	246·98	−1·36	+3·00	+6·57	7·22	335·5
	22	259·20	−1·35	+1·76	+6·32	6·46	344·4
	23	271·43	−1·34	+0·47	+5·82	5·84	355·4
	24	283·66	−1·33	−0·86	+5·06	5·13	9·6
	25	295·88	−1·32	−2·19	+4·07	4·62	28·3
	26	308·10	−1·31	−3·50	+2·91	4·55	50·3
	27	320·32	−1·30	−4·74	+1·61	5·01	71·2
	28	332·53	−1·29	−5·85	+0·22	5·85	87·8
	29	344·74	−1·28	−6·75	−1·20	6·86	100·1
	30	356·94	−1·27	−7·38	−2·60	7·82	109·4
Oct.	1	9·13	−1·25	−7·74	−3·90	8·67	116·7
	2	21·32	−1·24	−7·46	−5·03	9·00	124·0
	3	33·50	−1·23	−6·81	−5·92	9·02	131·0
	4	45·67	−1·21	−5·66	−6·46	8·59	138·8
	5	57·83	−1·19	−4·06	−6·61	7·76	148·4
	6	69·99	−1·18	−2·12	−6·30	6·65	161·4
	7	82·14	−1·16	+0·01	−5·55	5·55	180·1
	8	94·29	−1·14	+2·13	−4·39	4·88	205·9
	9	106·44	−1·11	+4·06	−2·93	5·01	234·2
	10	118·60	−1·09	+5·66	−1·30	5·81	257·1
	11	130·76	−1·07	+6·84	+0·37	6·85	273·1
	12	142·93	−1·04	+7·55	+1·97	7·80	284·6

Greenwich Midnight.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1900.	°	°	°	°	°	°
Dec. 28	0·18	+0·92	−0·92	−5·50	5·58	170·5
29	12·34	+0·94	+0·05	−4·39	4·39	180·7
30	24·48	+0·97	+1·02	−3·01	3·18	198·7
31	36·62	+0·99	+1·95	−1·45	2·43	233·4
1901.						
Jan. 1	48·76	+1·02	+2·82	+0·19	2·83	273·9

The longitudes are reckoned in the plane of the Moon's equator, the axis of reference being the radius which passes through the mean centre of the visible disc. This axis therefore rotates with the Moon, and is not fixed in space.

The inclination of the Moon's equator to the ecliptic is taken as 1°·523, the value used in the *Connaissance des Temps*, that given by the *Nautical Almanac* being 1°·536.

The physical librations in longitude and latitude, as given by Professor Franz's formulæ, have been applied; their values are taken from the *Berliner Jahrbuch* for the days given there, and interpolated by a graphical method for the other days. But the signs in the *Jahrbuch* require to be reversed in order to reduce to the system used here.

The colongitude of the Sun is 90° (or 450°) *minus* his selenographical longitude. It also is the selenographical longitude of the morning terminator reckoned eastward from the mean centre of the disc. Hence its value is approximately 270°, 0°, 90°, 180° at new Moon, first quarter, full Moon, last quarter respectively. The longitude of the evening terminator is of course 180° greater or less than that of the morning one.

When the geocentric libration in longitude is positive, the region brought into view is on the west limb; when negative, on the east.

When the geocentric libration in latitude is positive, the region brought into view is at the Moon's north pole; when negative, at the south.

The column "Combined Amount" gives the distance between the apparent and mean centres of the disc, and the column "Direction" gives the position-angle of the apparent centre from the mean centre, or, which is the same thing, the position-angle of the region which is most carried into view by libration. The angles are reckoned eastward from the northern extremity of the Moon's axis.

The terms "East" and "West" are used throughout with reference to our sky, and not as they would appear to an observer on the Moon.

Benvenue, 55 *Ulundi Road, Blackheath, S.E.*
1900 *February* 13.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. APRIL 11, 1900. No. 7

E. B. KNOBEL, Esq., PRESIDENT, in the Chair.

Thomas C. Bush, Somerville, Wells Road, Bath, was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Louis Napoleon George Filon, M.A., Fellow of and Lecturer on Astronomy at University College, London, Godwin House, St. Augustine's Avenue, South Croydon (proposed by H. F. Newall);
Forest Ray Moulton, Ph.D., Instructor in Astronomy at the University of Chicago (proposed by George E. Hale);
William Harrison Pearsall, Higher Grade School, Dalton-in-Furness (proposed by H. A. Wassell).

Seventy-eight presents were announced as having been received since the last meeting, including, amongst others:—

Royal Observatory, Cape of Good Hope, Reference Catalogue of Southern Double Stars, and Catalogue of 2789 Zodiacal Stars; Royal Observatory, Greenwich, Observations, 1897; Harvard Observatory Annals, Vols. 32, 33 (Visual Observations of the Moon and Planets, W. H. Pickering; Miscellaneous researches); Lund Observatory, Observations des étoiles de la

zone entre 35° et 40° N.; Paris Observatory, Carte photographique du ciel, Zone 24 (24 Charts), presented by the Observatories; S. de Glasenapp, Mesures micrométriques d'étoiles doubles; H. L. Rice, Theory and Practice of Interpolation; G. V. Schiaparelli, Osservazioni del pianeta Marte, 1888, presented by the authors; Photographischer Mond-Atlas, Heft 7, 8, presented by Prof. Weinek; Photograph of a meteor (lantern slide and enlargement), presented by C. P. Butler; Bronze copy of the Jubilee Medal of the Royal Meteorological Society, presented by the Society.

On Stationary Radiants of Meteors. Reply to the Criticisms of M. Th. Brédikhine. By H. H. Turner, M.A., F.R.S., Savilian Professor.

In *Monthly Notices, R.A.S.*, vol. lix. p. 140 (1899 January), I suggested an explanation of the stationary or long-enduring radiant points which Mr. W. F. Denning has so long and faithfully declared to be the outcome of his observations. In the *Bulletin de l'Acad. Imp. des Sciences de St. Pétersbourg* for January last (T. xii. No. 1), M. Th. Brédikhine has done me the honour to examine my suggestion at some length, though he ultimately dismisses it as leading to a totally different result from that which it endeavours to explain. He declares that I have forgotten to take account of the fact that the Earth's path is curved, and that my explanation would only hold good if the Earth moved in a straight line. I hope, however, to show that the mistake is his own, and that my suggested explanation remains untouched.

My suggestion was briefly this. Suppose we have originally a swarm of meteors crossing the Earth's orbit at a point N_0. The action of the Earth in passing again and again through the swarm will cause some of the meteors to describe new orbits crossing the Earth's orbit at a point N_1 displaced from N_0 in the direction opposite to that of the Earth's motion, but without altering the average *relative* motion of the Earth and meteors. Some of these, again, will be caused to describe new paths crossing the Earth's orbit at N_2, and so on, so that ultimately, instead of the point N_0, we have a long series of points N_0 N_1 N_2.

In the ordinary language of meteoric theory the point N is called the node, and it is a quite familiar idea that the node should be made to regrede in this way by the perturbations of the Earth. I merely avoid using this familiar language because there are two unfamiliar ideas on which I wish to insist which are liable to be overlooked if we think of the motion of the node as it would occur for a planet. These points are:

First, that the crossing-point of the swarm does not move as a whole; for some members of the swarm it remains unaffected, for

others it moves rapidly, and for yet others it moves with intermediate velocities, so that instead of a single crossing-point we ultimately get a series distributed round the orbit. Hence instead of the familiar retrogression of the node we have a *distribution* of the crossing-point along the orbit. I have given the reasons for this view in my paper above quoted, and as M. Brédikhine does not criticise them, I do not reproduce them here.

Secondly (the main point of my paper), the velocity of the meteors at the crossing point *relative to the Earth* remains unchanged during the displacement or distribution. Now, for this perfectly definite geometrical notion M. Brédikhine has substituted a completely different one, as follows: Suppose we draw from the crossing-point N a line NR to represent the relative velocity of the meteors in magnitude and direction, and a line NA to represent the absolute velocity or velocity in space, and let NE represent the velocity of the Earth. My principle (reasons for which are given in my paper at some length) is that NR remains constant in length and direction. Hence NA, which is obtained by combining NR with NE, varies both in length and direction as N moves round the orbit. There is no difficulty in tracing these changes if this be desired; but it is clear that the simplest account of what happens is given in terms of NR and not of NA. Nothing could be simpler than that NR remains constant.

M. Brédikhine, however, fixes his attention upon NA, the velocity in space. He assumes that NA remains constant *in length* and in *direction relative to NE*. In fact he assumes that as N rotates round the orbit it carries with it the two lines NE and NA as though they were rigidly attached to the radius SN from the Sun to node. Naturally, therefore, the diagonal NR of the parallelogram formed by NA and NE rotates with them, and is anything but fixed in direction. There is no need to prove this by a page of spherical trigonometry (p. 114 of M. Brédikhine's paper), and it may save others wading through an argument which would have been made easier by a figure if I point at once to the place where M. Brédikhine has made this wholly unwarranted assumption, viz. at the top of p. 115 of his paper, where he writes

$$l' = l - 5^\circ, \quad b' = b.$$

Here l and b are the longitude and latitude of the velocity of the meteors in space when the node is in a position N, and l' b' are the longitude and latitude when N has moved through 5°. This shows that he treats NA as rigidly attached to the radius vector SN (or the direction of the Earth's motion NE, which amounts to the same thing) in *direction*; that he treats it as constant in magnitude is less obvious, but appears from the derivation of the coordinates (λ' β') for the relative velocity, *i.e.* for the radiant. He even takes the trouble to convert longitude and latitude into R.A. and Decl., as though that might affect matters!

Now, I cannot but think that this complete misconception of my meaning arises from regarding the phenomenon to which I wished to draw attention as a motion of the node, with the associations which this familiar idea calls up. M. Brédikhine has visualised the actual orbit of the meteors as being simply rotated about the Sun; this is very far indeed from the conception I wish to put before astronomers. It may be that my conception is not deducible from facts, though I feel more and more convinced of its truth myself; but at any rate, if true, it leads at once to a stationary radiant—there ought not to be the least difficulty in admitting so much. If, on the other hand, M. Brédikhine's conception is deducible from facts, I should be the first to acknowledge that a radiant cannot be stationary, without any calculations at all; but I cannot see that anything he has said in his paper supports his view in the least degree. His investigation in the earlier part of the paper as to what happens to a meteor after a pair of encounters with the Earth supports, so far as it goes, either my view or his own: he proves that a small motion of the node will result; but he proves nothing conclusive as to the changes in velocity either real or apparent; indeed, he never examines the velocity of the meteor at all—he merely *assumes* that the velocity in space remains sensibly parabolic, and this assumption I regard not only as unproved but as quite erroneous.

As the principles I have advocated are thus apparently liable to be misunderstood, I will venture to repeat in somewhat different form my main argument.

If the Earth were at rest, and a meteor passed near it, its path would be deflected. The whole effect of the Earth's action may be summed up by considering the state of affairs when the meteor enters the "sphere of influence" of the Earth and when it leaves it.

(*a*) The magnitude of the velocity at entering and leaving is the same.

(*b*) But the direction is altered, being deflected in a plane through the Earth's centre.

(*c*) The time of passing through the sphere of influence is shortened; that is, if the time which would be spent within this sphere if the Earth were annihilated be T, then, when the Earth is replaced, the time will be $T-t$; because the velocity of the meteor is always increased by the Earth's attraction and never diminished.

Now, by assuming a *pair of* passages through the sphere of influence symmetrically disposed on opposite sides of the Earth we have

(*a*) The magnitude of the velocity still unchanged.

(*b*) The deflections being equal and opposite in the two cases neutralise each other, and the total deflection is zero. Hence the velocity is now the same on leaving the sphere *in magnitude and direction* as on entering it. [As regards the magnitude,

however, there may be a diminution of the kind suggested at the end of this paper.]

(*c*) The total time spent within the sphere of influence is still further shortened. Hence, let us disregard entirely what happens while the meteor is within the sphere of influence; suppose, for instance, that we entirely lose sight of it, and only know the following facts :—

It enters with a certain velocity.

If there is no Earth inside the sphere it emerges with the same velocity after time T.

If there *is* an Earth inside it emerges still with the same velocity, but after a shorter interval, $T-t$.

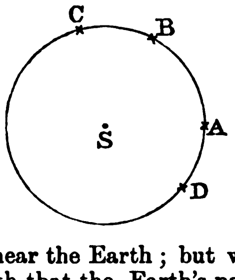
Now, what is true for the actual motion of the meteors when the Earth is at rest is true for the relative motion when the Earth and meteors are both in movement and both acted on by the same forces, as, for instance, the attraction of the Sun. The attraction of the Sun on Earth and meteors while the latter are within the sphere of influence of the Earth is sensibly the same; the difference is the "disturbing force" of the Sun familiar in lunar theory, very small even for the Moon, and very much smaller for meteors passing close to the Earth—in fact, quite negligible.

Hence, the meteors obey the laws above stated for their relative motion, viz.—

They ultimately emerge from the sphere of influence with the same velocity *relative to the Earth* with which they entered it.

This happens whether the Earth is existent within the sphere or is supposed annihilated; the only difference is that in the former case the meteors emerge after a time $T-t$, in the latter after a longer interval T.

Now, remark that these laws hold *independently of the time spent within the sphere of influence.* We cannot extend this time indefinitely, for that would mean that the meteor would describe



a complicated orbit near the Earth; but we can suppose it extended to such a length that the Earth's path is sensibly curved during the period. Let, then, T be a sensible fraction of a year, so that the Earth's path can no longer be taken as straight, but is sensibly curved. [M. Brédikhine has suggested that I have been misled by considering only a small straight portion of the path. I think he is mistaken.]

Let, then, T be such a time that during it the Earth describes an arc AC (much exaggerated in the figure) of its orbit round the Sun S; and let the meteors enter the sphere of influence at A. If we suppose the mass of the Earth annihilated they will emerge again with the same relative velocity at C. The effect of the Sun's attraction has been to make both Earth and meteors describe the curved path AC during the interval, but has not disturbed their relative motion, which remains unchanged throughout.

We need not suppose the Earth annihilated, but merely that it does not happen to be at A when the meteors come. The sphere of influence can still be described, but it is to be regarded as empty. This may happen many times, and the meteors will continue to enter at A and emerge at C, their orbit forming a sort of long contact with that of the Earth.

But there will come a time (the periods of Earth and meteors being incommensurable) when some meteors arrive at A to find the sphere of influence with an Earth inside it. The effect will be that they will be ejected earlier than before, say at B; but still with relative velocity unaltered (if we are allowed to combine the effect of a pair of symmetrical encounters into one). Their orbit will at the next return enter the sphere of influence at D and leave it at B, where AD = BC;* and unless another encounter with the Earth occurs, the orbit will be permanently shifted round through the arc CB, or AD. But the velocity of the meteors *in space* at D is not the same as the *velocity in space* was at A either in magnitude or direction; nor is it obtainable from the velocity at A by rotation round S as M. Brédikhine suggests: the arc AC is subject to such a simple rotation and becomes the arc DB, but to find the new velocities in space at D and B we must combine with the *unchanged relative* velocity, the changed velocities of the Earth.

The constancy of the relative velocity is in fact maintained quite independently of what happens to both Earth and meteors during the time spent in the sphere of influence so long as both are affected equally. Suppose, for instance, that a giant comet were to rush by during this time and cause a considerable change in the orbits of both Earth and meteors. The relative motion at parting would still be unchanged, which means that these meteors would still come from the same radiant point as before.

May I now consider a weakness in this theory of the distribution of the crossing-point round the Earth's orbit which was pointed out by Professor S. Newcomb, who very kindly discussed it with me at some length during his visit to Oxford last year? I have

* This is easily seen by considering all the motions reversed when the meteors are about to leave the sphere of influence. In the first case, if they are sent back again at C they emerge after time T at A. If sent back again at B, and if now the Earth be absent from the sphere of influence, they will similarly emerge again after the same time T at D, where CA = BD, or CB = AD. The orbit of the Earth is of course here regarded as circular.

thought over his criticism many times since, and I think it may be answered. It may be stated as follows : Admitting for the sake of argument that the perturbing action of the Earth on a meteor swarm is of the kind described in my paper and briefly reproduced above, it is so small at any one encounter that a large number of encounters and a long period of time are necessary for any sensible distribution of the crossing-point. Now, the general perturbations exercised by the other planets on the orbit of the meteor swarm will cause it to slowly change, so that those meteors which passed close to the Earth at one time will gradually pass further and further from it, new ones taking their place. The action required will thus never accumulate to sensible proportions.

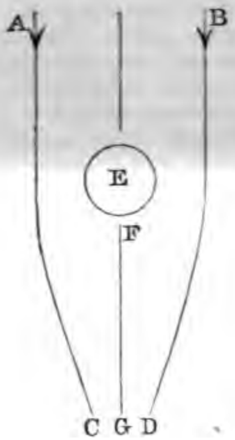
My answer to this very pertinent objection is as follows :—

In the first place, if we assume that the velocities of meteors are parabolic, their velocities relative to the Earth are so large, and they rush through the sphere of influence so quickly, that the effect I have indicated is certainly small. I have shown how small it is in my previous paper. But are we very clear as to the size of these velocities? Our knowledge of meteoric velocities is based on very scanty information. Mr. Denning is of opinion that it is worth very little, and he has a right to an opinion if anyone. Photography may ultimately help us in this respect; but meanwhile it will be well not to be too sure that the relative velocities of meteors and Earth may not be comparatively small. There is no reason why some meteors should not be describing orbits rather like that of the Earth ; indeed, there are many reasons why they should. If the relative velocity is small the distribution of the crossing-point may be effected with much greater rapidity.

Secondly (and here I make the suggestion with some diffidence, but yet I think it worth making), is it not possible that the Earth has an attractive effect on the orbits of meteors passing near it, so that those which would otherwise be carried away by planetary perturbation are retained, and perhaps even those which originally passed wide of the Earth's orbit are drawn towards intersection with it? If this were the case it would explain several things—not only would it complete the above theory of stationary radiants without any difficulty, but it would explain the large number of meteors encountered by the Earth without assuming that all space was full of meteor swarms.

To show how such an action might be possible, take the case with which I originally started, of two meteors, AC, BD, passing on opposite sides of an Earth, E, supposed at rest. Their paths are deflected towards each other equally and in opposite directions ; so that, if everything were exactly symmetrical, the meteors would collide after the encounter. If they were perfectly inelastic they would then proceed together along the central line FG with diminished velocity, viz. the resolved component of the deflected velocities in the direction FG.

Now, to imagine two single meteors meeting in collision in this way is almost ridiculous. But when we consider a whole swarm of meteors originally travelling in parallel lines, then there will be after the passage near the Earth a considerable convergence of the swarm towards the line FG, which will almost certainly result in a number of collisions or entanglements, the general effect of which would be (except in the improbable case of the meteors behaving like perfectly elastic particles), that some of the velocities perpendicular to FG, the general direction of motion, would be destroyed. The convergence is symmetrical with respect to the line FG (other things being equal), and for inelastic particles we can imagine a complete destruction of velocity perpendicular to FG, so that all the paths then coincided with FG. At the next return the meteors so affected would then all pass through the position occupied by



the Earth's centre. If the Earth were still there, they would of course fall on the Earth and be seen as meteors; if not they would pass through this point on the Earth's orbit instead of all passing wide of it as before; and this is exactly the sort of action above suggested—a tendency to draw the points in which the meteor orbits cut the ecliptic nearer to the actual path of the Earth. To suppose the whole swarm symmetrically distributed round the Earth, and the subsequent collisions to resemble those of inelastic particles, is of course an extreme supposition; but it is one towards which the actualities must approximate in some degree, and hence cause is shown for a tendency in the direction indicated.

We may regard the matter from another and more familiar standpoint. When we see in the sky a nebula with a nucleus we do not find any difficulty in imagining that the nebu-

lous matter is condensing towards the nucleus; indeed, it is the natural supposition. It would be still perfectly natural if the nucleus, instead of being permanently in place, were to appear there only at comparatively rare intervals, being annihilated in the meantime. The condensation would proceed more slowly, but would proceed nevertheless. If, again, the nucleus made these visits by actually passing through the nebulous mass periodically along a certain line, then the condensation would be towards this line generally, and not towards any particular point of it. If, further, the path of the visiting body were not a fixed line, but any one of a series of lines forming a surface, the condensation would be towards this surface.

Now, this is surely just what is happening with a meteor swarm. To a spectator carried with the swarm, and unconscious of its motions in space, the Earth appears as a periodical visitor passing through the swarm. Its path always lies on a certain surface, viz. the surface described in the swarm by the Earth's orbit whenever the swarm crosses this orbit. Hence the swarm will gradually condense towards this surface, and so *tend* to become a sheet which passes through the Earth's orbit, or rather through which the Earth's orbit sweeps at successive returns. This tendency may not be very strong, owing to the rarity of the Earth's visits, but I do not see why it should not be stronger than the perturbing influence of the other planets, considering their remoteness compared with the proximity of the Earth. Such considerations would only apply to swarms which originally passed near the Earth. Those in the neighbourhood of other planets would be similarly collected by them into sheets passing through *their* orbits; and in the case of the giant planets, like *Jupiter*, the condensation would be much greater. Could these condensations of meteor swarms ultimately form comets? Have we here a clue to the established connection of comets and meteors, and to the association of periodical comets with the major planets?

That such general speculations are hazardous I am only too well aware. I put them forward with due apologies. My main point is this. We have the statement of a thoroughly experienced observer that certain meteor radiants are stationary or persistent. That this observer knows what he is saying is evident from the fact that he distinguishes other radiants which are *not* stationary; and, further, there are tests which may be applied to his observations generally which have not yet shown them to be otherwise than excellent. Starting, then, from this observed fact, can we suggest an explanation of it? M. Brédikhine's "explanation," of course, does not count, as it is a simple denial of the main fact. Mr. Denning claims the physical connection of certain radiants appearing in the same part of the sky in different months; M. Brédikhine denies the physical connection, and attributes the connection to chance, and in this he has a large following. Is there any good reason for this scep-

ticism or positive disbelief until possible causes for the fact have been examined? I have endeavoured to indicate a possible cause in the simple attraction of the Earth. The considerations I have adduced are not very thoroughly established, but they point in the right direction, and do not demand any new supposition. Further, they are not at variance with known results of more elaborate mathematical investigations; and that they are not capable of being fully confirmed by, or compared with, such results at once is due to the fact that mathematical investigations have not yet been carried far enough. The perturbations of a planet on a swarm of meteors considered as a whole have been examined, but not the selective action on different parts of the swarm, and certainly not the interaction of differently affected parts. Until this has been done, why should we deny the possibility of the facts which Mr. Denning claims as observed facts?

Observations of the Leonids made at the Cambridge Observatory on 1899 November 13, 14, 15. By Arthur R. Hinks, M.A.

1. The observations to be discussed were made by a number of members of the University who had volunteered to assist in securing as complete a record as possible of the expected Leonid shower. My acknowledgments are due, first, to Mr. John C. W. Herschel, B.A., Research Student in Astronomy, St. John's College, who has taken a large part in the preparations, observations, and discussion of the results; and, secondly, to the following gentlemen: Messrs. J. F. Cameron, B.A., Fellow of Caius College; L. E. H. R. Barker, B.A., A. L. Hall, B.A., and H. E. Wimperis, Caius College; R. W. H. T. Hudson, B.A., A. B. Field, and M. Walker, St. John's College; W. E. Hartley, B.A., and G. W. Walker, B.A., Trinity College; F. M. Oldham, B.A., Trinity Hall.

We attempted three things:—

I. A continuous count of all meteors seen (five observers).
II. Records of trails from visual observations (two observers and a timekeeper).
III. Records of trails photographically (three observers).

The weather was on the whole not unfavourable, though we suffered from a thick haze late on the night of the 14th, when the shower was least feeble.

I. Horary numbers of observed Leonids.

2. Four observers watched continuously on the nights of the 14th and 15th, dividing the sky among them; and a fifth recorded every five minutes the counts of the four. The numbers

of meteors recorded as Leonids are given below. It is probable that meteors from neighbouring radiants have not been entirely eliminated from the count:

1899 Nov. 13.		Nov. 14.		Nov. 15.	
		h m h m		h m h m	
Clouds with occasional breaks until 17^h, then clear.		12 5 to 13	4	12 25 to 13	2
		13 ,, 14	13	13 ,, 14	9
h h m		14 ,, 15	17	14 ,, 15	11
17 to 18	20	15 ,, 16	8	15 ,, 16	5
18 ,, 18 25	3	16 ,, 16 35	3	16 ,, 17	19
		From $14\frac{1}{2}^h$ fog gradually rose, and after $15\frac{1}{2}^h$, only brighter stars visible. Clouded over at $16\frac{1}{2}^h$.		17 ,, 18	21
				18 ,, 18 30	5
				From $15\frac{1}{2}^h$, light clouds at times	
Totals	23		45		72

In his spare time the recorder attempted an estimate of the magnitudes of any meteors he saw:

	Nov. 13.	Nov. 14.	Nov. 15.
a. Brighter than Jupiter	0	3	3
b. Between Jupiter and α Leonis	3	9	14
c. Between α and η Leonis	6	15	16
d. Fainter than η Leonis	6	11	18

II. Radiant points deduced from the visual observations.

3. Charts for recording the trails were prepared as follows:—The coordinates of all stars down to the fourth magnitude in a field having a radius of about 65° around the radiant were calculated for a gnomonic projection on the plane tangent to the sphere at the radiant. From these a map was plotted on millimetre paper to the scale tan 45°=1=100 mm. A set of needles of graduated diameters, broken across, and with the ends ground flat, were mounted in wooden handles. Sheets of paper, dark blue one side and white the other, were laid, half-a-dozen at a time, blue side downwards, between the map and a sheet of lead, and the stars were punched through with needles of sizes appropriate to the magnitudes. The charts were laid on a tall desk of which the top was ground glass, and were illuminated from below by electric light. The stars stood out bright on a dark-blue ground, which did not dazzle the eye; and the trails were drawn in pencil on the white side, which was uppermost, by means of transparent celluloid rulers, of which not much more than the edge was visible on the charts. This plan was suggested to me by Mr. Herschel. It is entirely satisfactory; and the

only modification we shall make on a future occasion will be the substitution of night-lights for electric lamps. The heat from the latter was not sufficient to keep the charts from being covered first with dew and then with ice.

A copy of the chart, with a catalogue of the positions of the stars on the gnomonic projection, is placed in the Library.

4. The number of trails plotted was :

November	13	15.
„	14	11.
„	15	33.

Of these there were many that came from the general direction of *Leo*, but were clearly not true Leonids, and it was necessary to decide which should be included in the determination of the radiant point. Denning has given in the *Observatory* (1897, xx. 306), and in his General Catalogue (*Memoirs R.A.S.* vol. liii.) the positions of a number of radiants near *Leo*, all of which furnish in November swift streak-leaving meteors indistinguishable in appearance from Leonids. These were afterwards plotted on the map. They are clustered so thickly round *Leo* that it is somewhat difficult to pick out a trail which cannot be assigned with some probability to one or more of them. Even the small number of observations which we obtained gave, however, some evidence confirming the existence of definite radiation from two of these points ; and this will be considered later.

We eventually decided to reckon as true Leonids seven trails on the 13th, eight on the 14th, and eleven on the 15th.

In two or three cases the same meteor was plotted on two maps. These have been reduced as if they were observations of separate meteors, which is a convenient method of weighting the doubly observed meteor if the radiant is assumed to be strictly a point, but is perhaps not quite justifiable if it is an area of which we wish to determine the mean centre.

5. The displacement of the position of the apparent radiant point due to the attraction of the Earth on the meteors was calculated according to the theory of Schiaparelli. Tables for facilitating the computation are given in his treatise, "Entwurf einer astronomischen Theorie der Sternschnuppen," pages 65 and 109 ; and are reprinted in Valentiner's "Handwörterbuch der Astronomie," vol. ii. pp. 167, 168.

I assumed that the apparent radiant on November 14, 15^h was in R.A. 149° Decl. +23° (Clark, *Monthly Notices*, 1899 December, vol. lx. p. 169). The elongation ψ of the apparent radiant from the apex of the Earth's way was then 9°·8.

Assuming for the major axis of the meteor orbit 10·34 we have for the velocity of the meteors at their node on the Earth's orbit $v=\sqrt{1\cdot 90}$, the velocity of the Earth being taken as unity.

The undisturbed velocity of the meteors relative to the

Earth comes out $u_0=2\cdot353$; the velocity is increased by the Earth's attraction to $u=2\cdot383$; and the apparent radiant when on the horizon is displaced towards the zenith by an amount $\Phi=0° 43'\cdot8$.

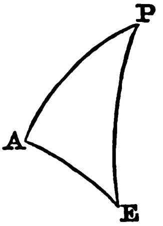
The displacement η for a given zenith distance ζ is then

$$\tan \tfrac{1}{2}\eta=\tan \tfrac{1}{2}\Phi \,.\, \tan \tfrac{1}{2}\zeta.$$

If q is the parallactic angle the displacements in R.A. and Decl. are $\eta \sin q$, $\eta \cos q$ respectively. Their values are given in the table :

Hour-angle.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
$\eta \sin q$	−20′·6	−17′·9	−14′·6	−11′·2	−7′·5	−3′·4	0′·0
$\eta \cos q$	+24·4	+20·1	+16·8	+14·4	+12·7	+11·8	+11·4

6. The displacement of the position of the apparent radiant due to the rotation of the Earth was calculated as follows :— Let P be the pole ; A the apparent radiant ; E the apex of the



diurnal motion of the observer ; that is, the eastern point of the celestial horizon.

The velocity of an observer in the latitude of Cambridge is 0·285 km. per second ; and the velocity of the meteors, corresponding to $u=2\cdot38$ is 70·4 km. per second. If then $k=\frac{0\cdot285}{70\cdot4}$ ($\log k = \bar{3}\cdot6072$) the displacement of A towards E is very nearly $k \sin$ AE. And if h is the hour angle west of A

$$\begin{aligned}\text{displacement in R.A.} &= k \sin \text{AE} \sin \text{PAE}\\ &= k \cos h.\\ \text{displacement in decl.} &= k \sin \text{AE} \cos \text{PAE}\\ &= k \cos \text{AP} \sin h.\end{aligned}$$

The values of these displacements for the Leonid radiant are given in the table :

Hour-angle.	18h.	19h.	20h.	21h.	22h.	23h.	24h.
$\Delta\alpha$	0′·0	+3′·6	+7′·0	+9′·8	+12′·0	+13′·5	+13′·9
$\Delta\delta$	−5·4	−5·3	−4·7	−3·8	−2·7	−1·4	0·0

7. The Leonid shower extends over so few days that it does not seem possible at present to decide whether (1) the *true* radiant is stationary, and consequently the motion of the *apparent* radiant in latitude and longitude variable; or (2), as in the case of the Perseids, the motion of the *apparent* radiant is uniform in longitude and zero in latitude, in which case the *true* radiant is not stationary.

I have therefore not attempted to include in the reduction the effect of the orbital motion of the Earth, but have reduced each day's results separately.

8. The diagram exhibits the motions of the apparent radiant due to the separate effects of the attraction of the Earth and its rotation, and also the resulting motion due to the combination of the two.

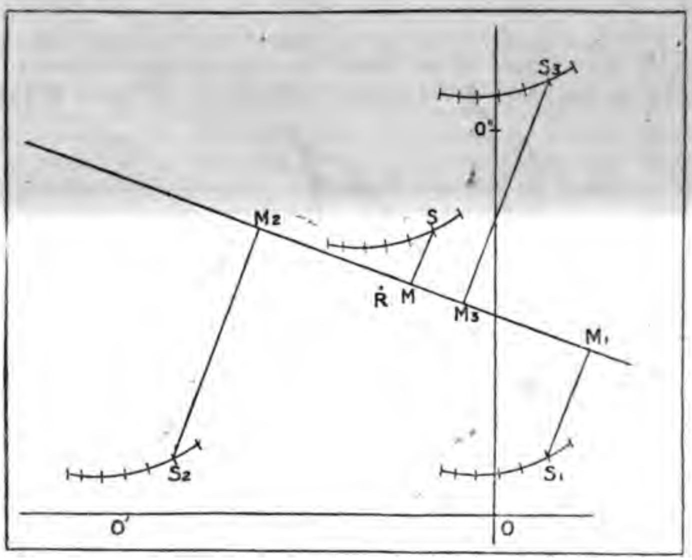


FIG. 1.

9. The radiant points were derived by an elegant graphical process given by Schiaparelli on p. 254 of his treatise (German edition).

The prolongation of the trails near the radiant point were transferred to millimetre paper on a scale ten times the original maps.

Let O be the origin of coordinates; R the position of the undisturbed apparent radiant to be derived from our observations; S the point on the curve of position of the displaced radiant corresponding to the time of appearance of a meteor; SM the perpendicular upon the observed trail. Schiaparelli

shows that if R is the most probable radiant given by the observations the sums of the projections upon the coordinate axes of all the perpendiculars such as SM are each zero.

We can therefore determine R as follows :—Take two points O′ O″ on the axes. Draw about O, O′, O″ as origins the curves of displacement of the apparent radiant. From the points on these corresponding to the time of appearance of meteor draw the perpendiculars on its trail. (In practice find by a square the feet of the perpendiculars, and read off their coordinates directly.)

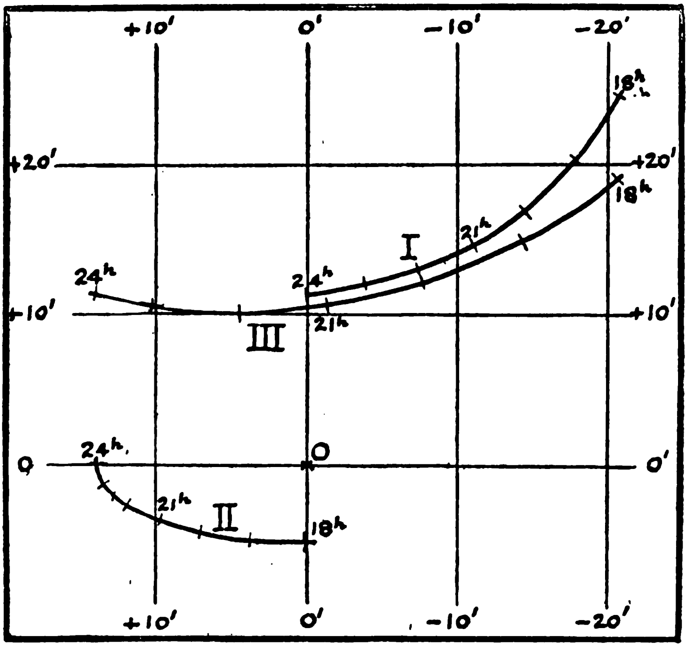


Fig. 2. O is the undisturbed radiant.
I ,, Zenith Attraction curve.
II ,, Diurnal Aberration curve.
III ,, combination of I and II.

If now the sums of the projections on the axes of all the perpendiculars of the three sets O, O′, O″ be S, T ; S+ΔS, T+ΔT ; S+Δ′S, T+Δ′T ; the coordinates x, y of R are given by

$$o = S + \frac{x}{OO'} \cdot \Delta S + \frac{y}{OO''} \cdot \Delta' S.$$

$$o = T + \frac{x}{OO'} \cdot \Delta r + \frac{y}{OO''} \cdot \Delta' T.$$

The observations for the three nights were treated in this manner, and the rectangular coordinates of the apparent radiants referred to an origin in R.A. 150°; Decl. +22° (the centre of our projection) were

Date.	x m	y m	Mean Deviation. m
Nov. 13	−0·043	−0·017	0·025
14	−0·044	+0·003	0·017
15	−0·008	+0·001	0·022

The unit is tan 45°=1=1 metre; and the corresponding positions of the radiant are

	R.A. °	Decl. °	Mean Deviation. °
Nov. 13	147·4	+21·0	1·4
14	147·3	+22·2	1·0
15	149·5	+22·1	1·3

Note.—The R.A. of the radiant on November 14 has extremely little weight: it depends practically on three trails, two of which are observations of the same meteor, which may well have belonged to the subsidiary shower B. (See below.)

When the coordinates of the apparent radiants had been found, the curve of position of the displaced radiant was drawn for each night, and the perpendiculars from the proper points on these curves to the respective trails were measured. The mean value of the perpendicular is given under the heading "mean deviation," and affords a criterion of the accuracy of the selected observations.

10. *Subsidiary Showers.*—We obtained four meteors on the 13th and four on the 15th, which might be ascribed to a subsidiary radiant A. Of these one was very probably a true Leonid, and has been included in the previous discussion. It is of course impossible to correct for zenith attraction &c. in the absence of knowledge of the true orbit. A graphical determination, similar to the above, of the most probable radiant from the eight paths gave

R.A. 153°·5, Decl. +37°·0.

Denning gives in his General Catalogue several determinations of a radiant which agree with this:

CXVIII. *μ Ursids.*

No. 15	155° + 35°,	Nov. 13–15,	1879,	Perry.
16	154 + 41,	14–17,	1885,	Denning.
17	154 + 37,	15,	1875,	A. S. Herschel.
18	155 + 35,	15,	1896,	A. S. Herschel and Corder.

There were also five meteors on the 15th which might be ascribed to a radiant B. Of these, one was very likely a true

Leonid. The trails were not well situated for an accurate determination of the radiant point. It is approximately

R.A. 146°·7, Decl. + 7°·4,

which is quite near the radiant given in the General Catalogue as

CXII. *o Leonids.*

No. 13 146° + 8°, 1891 Nov., Corder.

11. An attempt was made to photograph the trails with a 5-inch portrait lens on the Northumberland Equatorial. Only one trail was secured, on November 15, of a bright meteor nearly end on. Measurement of this trail is deferred until the arrival of our new measuring machine.

12. The method of Schiaparelli used here was adopted after a trial of several, because it seemed to combine quite admirably simplicity with rigour; and this note must be regarded as the account of an attempt to prepare and gain experience for the future, rather than as the presentation of results of observation of much weight in themselves.

Cambridge Observatory:
1900 *March* 26.

The Equatorial Current of Jupiter in 1898.
By A. Stanley Williams.

The very striking appearance of the great Red Spot in the year 1879 gave an immense impetus to the study of the planet *Jupiter*, particularly as regards the investigation of the motions of the various spots and markings; and as a result of this impetus we have available at the present time the results of researches extending over a period of more than twenty years. We are consequently now in a position to commence the discussion of certain questions having an important connection with the physical condition of the planet in a more satisfactory and intelligent manner than was before possible.

One of the most important of these questions is that connected with the changes which have been found to occur from time to time in the motions or velocities of certain spots and surface currents on the planet. Valuable papers on the changes in the motion of the Red Spot have already been published recently by Mr. W. F. Denning and Dr. O. Lohse,* and the changes which have happened, and are happening, in the velocity of the great equatorial current form a subject of perhaps not inferior importance. With regard to this latter subject, the

* See *Astr. Nach.* No. 3490, and *M. N.*, vol. lix. p. 574.

experience of the past twenty years shows, that, for the purpose of investigating the periodical or secular changes in the velocities of the various surface currents of *Jupiter*, it is very essential that the necessary data should be based upon all the available observations, so that the final results shall be as *definitive* as possible. The number of spots employed in the different determinations of velocity should be as great as possible, in order to avoid the local differences in the rate of motion which are found to affect individual spots; and the observations of each spot should extend over as long a period as possible, in order to eliminate the temporary variations which occur in the motions of most spots. Finally, the observations themselves should be numerous, in order that there may be no uncertainty with regard to correct identification. This last item is a very important one, as certain discordant results in the past must certainly be ascribed to incorrect identification.

A determination of the motions of the various extra-equatorial currents of *Jupiter* in the year 1898, based on the principles stated above, by the Rev. T. E. R. Phillips, has been published in the *Monthly Notices*, vol. lix. p. 79; and a similar one for the year 1899 in vol. lx. p. 210. The present paper contains the result of a similar definitive determination of the rotation period of the equatorial current in the year 1898, based likewise upon all the available observations. These observations are fairly numerous, the total number being 716, and 687 of these were made use of. The remaining twenty-nine observations relate to a few spots which were not sufficiently well observed for the purpose in view.

The method employed by Mr. Phillips of showing the observations in the form of charts is not so applicable to the present case, partly because of the numerous temporary changes or shifts in position of the individual spots, and partly on account of the difficulty that would arise from overcrowding. On the other hand, it is absolutely necessary that the observations should be published in some form or other, so as to enable other investigators to check, and if necessary to re-discuss, the results, and in particular to enable others to check the correct identification of the spots, upon which everything depends. I have, therefore, added at the end of this paper a complete list of the observed positions of the spots in as simple a form as possible.

The rotation periods of the spots were derived in the following manner. The observations were first plotted upon a chart similar to that in Plate 13, but on a larger scale, and with the difference that the whole of the observations were separately marked, not the mean values only. A thread was then stretched across the paper so as to lie as evenly as possible through the dots representing the observations of a spot. Two or three observations were then chosen near the beginning of the period of observation, and a similar number near the end, in such a manner that by comparison of these observations a rotation

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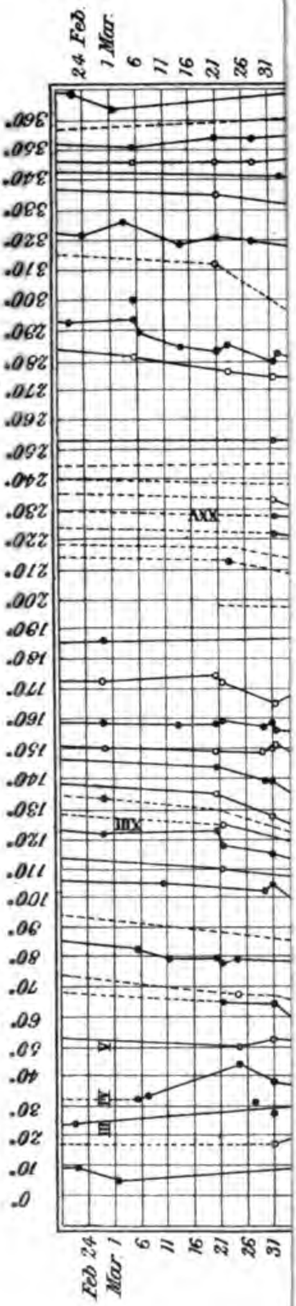

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period of the spot would be given corresponding as nearly as possible with that represented by the thread. This method was rendered necessary by the remarkable minor changes or wanderings in position of the equatorial spots, which wanderings will be very noticeable on reference to Plate 13. The observations which were chosen in this manner for computing the rotation periods are marked with an asterisk in Table II., but it should be clearly understood that they have usually been so selected as representing the whole body of observations, or the average motions of the spots, and not from any special significance or value of their own. Sometimes this method could not be adopted in its entirety, owing to the small number or peculiar grouping of the observations, and in such cases the nearest approach to it that was possible under the circumstances was made. On account of the wanderings of the spots being so considerable, I have not thought it necessary to add a column giving the residuals according to the adopted rotation periods of the spots, as the nature of these will be better gathered from the diagram, Plate 13.

In Table I. below will be found the concluded rotation periods of the spots, thirty-eight in number, derived in the above manner. The first column gives the number of the spot; the second, the rotation period; the third, the mean date to which such period refers; the fourth, the number of rotations performed between the first and last observations; and the fifth, the number of observations.

TABLE I.

Rotation Periods of the Spots.

Spot.	Rot. Per.	Date.	No. of Rotations.	No. of Obs.
	h m s			
I.	9 50 27·9	1898·36	385	26
II.	28·6	·32	409	27
III.	37·4	·20	100	5
IV.	25·5	·27	180	9
V.	19·9	·22	309	10
VI.	15·2	·37	278	23
VII.	21·6	·37	273	16
VIII.	19·0	·34	297	34
IX.	18·6	·39	229	35
X.	21·2	·35	297	40
XI.	25·0	·38	285	21
XII.	27·1	·34	324	29
XIII.	21·4	·31	173	5
XIV.	24·6	·35	341	10
XV.	29·3	·36	273	14

Spot.	Rot. Per. h m s	Date.	No. of Rotations.	No. of Obs.
XVI.	29·3	·34	229	18
XVII.	26·7	·35	341	38
XVIII.	27·5	·34	336	48
XIX.	26·6	·34	336	9
XX.	29·4	·23	314	5
XXI.	20·8	·37	278	5
XXII.	27·4	·34	110	7
XXIII.	20·2	·39	251	12
XXIV.	22·8	·41	200	6
XXV.	26·5	·39	251	8
XXVI.	27·9	·14	299	6
XXVII.	23·0	·30	44	6
XXVIII.	24·1	·39	156	4
XXIX.	24·3	·37	224	6
XXX.	19·6	·33	290	32
XXXI.	20·6	·32	319	38
XXXII.	17·5	·36	251	20
XXXIII.	17·8	·32	312	29
XXXIV.	15·6	·38	285	16
XXXV.	18·6	·39	256	12
XXXVI.	25·4	·33	285	27
XXXVII.	27·8	·31	251	24
XXXVIII.	9 50 21·2	1898·40	112	7

Giving all the above results equal weight with the exception of spots IV., XIII., XXI., XXII., and XXVIII., which were given $\frac{1}{2}$ weight; and spots III., XXVII., and XXXVIII., which were given $\frac{1}{4}$ weight, the finally concluded period of rotation of the equatorial current for the mean date 1898·34 is

$9^h\ 50^m\ 24^s{\cdot}0$ (from 38 spots).

The above spots were all situated on or close to the north edge of the south equatorial belt. For comparison with the above value we have the following results derived by several observers from their own observations alone :—

W. F. Denning : $9^h\ 50^m\ 23^s{\cdot}6$ (23 spots), *Monthly Notices*, vol. lviii. p. 481.

W. J. Hall : $9^h\ 50^m\ 33^s{\cdot}2$ (9 spots), *Memoirs B.A.A.*, vol. vii. p. 91.

T. E. R. Phillips : $9^h\ 50^m\ 24^s{\cdot}2$ (19 spots), *Ibid.* vol. vii. p. 89.

It should be mentioned that my identifications agree with those of Mr. Denning from his own observations with a few unimportant exceptions. From the close accordance between the results of Mr. Denning and Mr. Phillips* and my own, it appears that the mean rotation period of the current can be determined with satisfactory accuracy, notwithstanding the very striking wanderings of individual spots or groups of spots, and in spite of an occasional observation being wrongly identified, provided that both observations and spots are sufficiently numerous, and that the former extend over a considerable period of time.

It is quite possible that a few of my identifications may be at fault in the present instance, and in fact by referring to Plate 13 it will be evident that alternative identifications are possible in several cases. Nevertheless it is quite certain that no serious or even appreciable difference would be produced in the final result by the employment of any such alternative identifications. Good drawings or diagrams of the markings are often a material help in deciding doubtful cases, but unfortunately they are not always available.

Referring again to Plate 13,† in which the dark spots are represented by dots and the bright ones by circles, there are several interesting conclusions that may be drawn. Thus—

(*a*) There is a distinct tendency towards a collection of the spots into groups having slightly different rotation periods, and analogous to the state of things described by Mr. Phillips as existing in the north tropical current in 1899 (*Monthly Notices*, vol. lx. p. 214; and Plate 6), but not so well marked.

(*b*) The curious wanderings in position of nearly all the spots. These wanderings are undoubtedly real in most cases, and due to actual changes or shifts in position of the spots. They are on much too large a scale to be ascribed to errors of observation, and moreover some of the widest departures from uniform motion are supported by the independent observations of several different observers.

(*c*) The wanderings of one spot are generally synchronous with similar wanderings on the part of adjacent spots. This would seem to indicate as the cause some local disturbance affecting comparatively small regions of the planet.‡ It is note-

* Mr. Hall's observations are in excellent agreement with the others, and his mean period differs so considerably only because in several cases his observations happened to have been made when the motions of the spots were unusually slow. Spot XII., for instance, was observed between June 10 and June 17, and it will be seen from Plate 13 that the motion of this spot was abnormally slow at that time. The effect of these temporary variations in motion is practically eliminated if the observations extend over a period of several months.

† The motion of the red spot would be represented on this diagram by a straight line very nearly at right angles to the direction of motion of the equatorial spots.

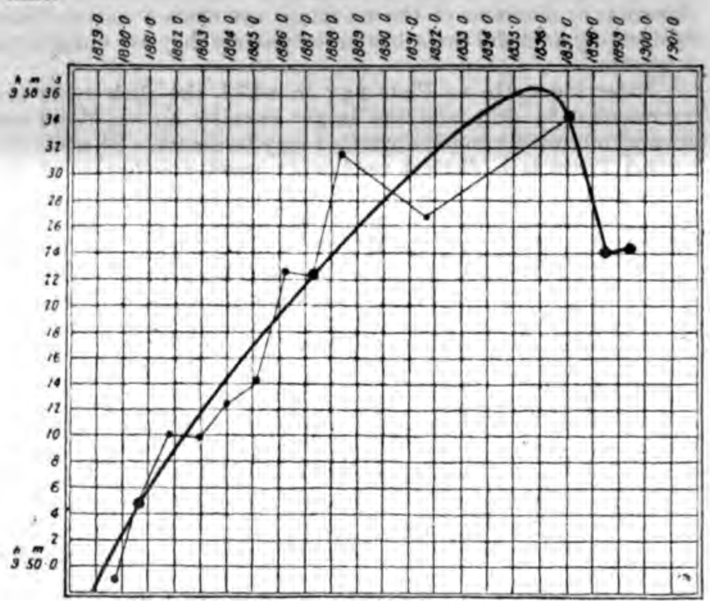
‡ In 1888, however, a remarkable disturbance of the same kind occurred which affected the *spots* over at least 250° of longitude.

worthy that in some cases, where several adjacent spots were affected, the wanderings of the spots grow less and less according as such spots were situated farther and farther away from the apparent centre of the local disturbance.

(*d*) Connected perhaps with these local disturbances is the tendency for some spots to subdivide, and again later on to reunite. Spot IX., for instance, split into two spots about April 15, which spots had reunited on May 4, whilst later on there was again a division into two.

(*e*) The manner in which spots III., IV., and V. either died out, were squeezed out, or else coalesced with adjacent spots seems worthy of note.

(*f*) The importance of having many observations of many spots covering a considerable period of time in order to satisfactorily determine the velocity of the equatorial current at any time.



The adjoining little diagram will show the present position with regard to the changes in the velocity of the equatorial current. The abscissæ represent time, and the ordinates rotation period or velocity.* The data prior to 1898 have been taken from *Monthly Notices*, vol. lviii. p. 14. The value for 1899 is the mean of the rotation periods derived by Mr. Denning and Mr. Phillips from their own observations. The large dots represent

* A change of 30ˢ in the rotation period is equivalent to an actual change of 22 miles (35 kilometres) an hour in the velocity of the current.

good determinations, depending upon a large number of spots. The small dots represent results based mostly on single spots. The 1880 result, resting as it does upon two spots and on several independent computations of rotation period, has been marked by a medium-sized dot. The thick black line shows the changes that have occurred in the velocity of the current during the last 21 years. The rotation period increased from $9^h\ 49^m\ 59^s$ in 1879 to a maximum of about $9^h\ 50^m\ 36^s$ in 1896, and from thence has diminished at a rather more rapid rate to 1898, when a distinct, though probably only temporary, check occurred. The form of the curve with this probably temporary check somewhat recalls the form of light curve of some variable stars, and also the curve of sunspot frequency between 1869 and 1872, as given in the diagram on p. 125 of Miss A. M. Clerke's *System of the Stars*, except that in the present case the descending curve is more abrupt than the ascending one. The velocity curve of the equatorial current also resembles closely in form the velocity curve of the Red Spot about the years 1854–61, as given in Mr. Denning's diagram in the *Monthly Notices*, vol. lix. p. 580. It is too early yet to enter into the question of periodicity; but, assuming the changes in velocity to be periodical, the period would seem to be a long one—probably at least 50 years, and possibly 100 or even more in length.

In Table II. the first column contains the date, the second the longitude of the spot according to "System I." of Mr. Crommelin's Ephemeris, and the third column a reference to the observer—namely:

B.=L. Brenner, Lussinpiccolo.
Bh.=D. Booth, Leeds.
D.=W. F. Denning, Bristol.
G.=J. Gledhill, Halifax.
H.=W. J. Hall, Nantwich.
M.=H. MacEwen, Glasgow.
P.=T. E. R. Phillips, Yeovil.
W.=A. S. Williams, Hove.

The longitudes were all derived from eye-estimates of the transits across the central meridian of the disc, with the exception of some of those due to Mr. Brenner, where the transits were taken across a micrometer wire bisecting the disc.

Observations marked with a * were used for computing the rotation periods of the spots. Those marked with a † were either noted as being unsatisfactory or approximate at the time, or else are based only on "estimated transits." A few apparently discordant positions are bracketed.

[redacted]

TABLE II.

Observations of Equatorial Spots.

Dark Spot I.

1898.	λ	Obs.	1898.	λ	Obs.
Feb. 22	8°·8*	H.	June 14	(355°·7)	G.
Mar. 2	3·8*	G.		4·2	M.
Apr. 4	8·7	W.	16	358·8	P.
	9·9*	H.	19	0·7	D.
13	9·7	W.	21	0·3†	P.
May 4	7·6	,,		2·9	M.
6	12·2	,,	28	0·3	D.
15	13·8	M.		2·7†	P.
29	1·4	,,	30	0·9	,,
June 5	359·7	P.	July 5	2·7*	D.
	0·4†	M.	7	356·3†	M.
7	358·0	,,		2·0*	D.
12	(354·5)	D.	30	359·6*	,,

White Spot II.

Jan. 20	22·1*	B.	June 5	17·5	W.
Mar. 31	16·7	M.		17·4	P.
Apr. 4	19·0*	W.	7	(8·4)	M.
	19·0*	Bh.	10	15·7	D.
	20·3	P.	14	18·9†	P.
16	20·4	Bh.		20·7	M.
18	24·5	P.	19	18·9*	D.
May 4	15·5	W.	21	18·2	M.
6	14·0	P.	28	14·9*	D.
18	20·8	D.		15·9*	P.
	21·3	G.	30	14·3*	,,
	24·3	P.	July 5	16·0*	D.
29	9·9	M.	7	16·4*	M.
June 5	13·8†	,,			

Dark Spot III.

Feb. 22	22·8*	G.	Mar. 31	27·7	M.
Mar. 28	30·7	P.	Apr. 4	30·3*	W.
31	26·0†	W.			

Dark Spot IV.

1898.	λ	Obs.	1898.	λ	Obs.
Mar. 5	31°·3*	W.	Apr. 16	32°·6	Bh.
8	32·6*	H.	May 6	22·6*	W.
24	43·6	M.	18	26·9*	D.
31	38·2†	W.	29	29·4†	M.
Apr. 4	34·9	H.			

White Spot V.

Jan. 20	59·9*	B.	Apr. 16	45·8	W.
Mar. 24	49·7	M.	18	43·4	P.
31	52·2	W.	30	41·1	"
Apr. 4	50·7	"	May 6	32·4*	W.
5	52·0†	M.	27	29·3*	"

Dark Spot VI.

Mar. 22	66·4*	W.	June 10	26·7†	P.
31	64·4*	"		27·3	D.
Apr. 5	56·3†	M.	14	34·1	M.
16	47·5	H.	19	30·2	P.
25	47·1	P.		33·6	D.
May 4	47·2	H.	21	35·8	M.
13	31·3	M.	28	28·4	D.
27	32·9†	"	July 5	27·2*	P.
	39·6	W.		31·5*	D.
June 5	29·7†	"	7	(39·0)	M.
	30·9†	M.	14	28·2*	"
7	36·5	"			

White Spot VII.

Mar. 24	67·4*	M.	May 11	50·0	P.
Apr. 25	55·6*	P.	27	43·9	M.
30	50·2†*	W.	June 3	51·4	W.
	55·1*	D.	10	43·8	P.
May 2	51·8	P.	19	43·0	"
4	50·2	W.	21	50·5	M.
	52·1	P.	July 5	41·9†*	P.
9	50·8†	W.	14	38·6*	M.

Dark Spot VIII.

Mar. 5	81·4*	W.	Mar. 20	79·0*	H.
12	78·8*	G.	22	75·9*	D.

1898.	λ	Obs.	1898.	λ	Obs.
Mar. 22	78°·0*	W.	Apr. 30	63°·6	W.
24	78·9	M.		64·3	D.
Apr. 7	78·1	D.	May 2	65·8†	P.
12	71·8	M.	4	64·0	"
16	71·0	Bh.	9	59·3	W.
	70·9	D.	13	56·9	M.
	70·8	W.	18	54·8†	"
	76·3	P.	27	57·3	"
	76·4	H.	June 3	60·6	W.
18	73·3	P.	10	57·2	D.
19	75·0	"	19	51·3*	"
23	71·8	W.		52·2*	P.
25	68·4	P.	July 3	50·8*	D.
	72·1	H.	5	48·5*	"
30	63·1	P.	14	(56·9†)	M.

White Spot IX.

Apr. 7	83·6*	D.	May 11	73·7	P.
12	81·6	M.	14	79·5	D.
	81·1	P.	16	74·8	"
13	81·9†	W.		78·4	P.
16	79·4*	D.	18	78·6	"
	81·9*	Bh.		79·3	D.
	82·9*	P.	June 1	76·9†	P.
	86·1*	W.	3	74·0†	W.
18	83·6†	P.	10	73·0	P.
19	84·3*	"		76·7	D.
	86·1*	D.	17	67·7	"
23	86·9	W.	19	67·4	P.
25	84·9	P.	July 3	57·6*	D.
30	81·3	W.		62·0†*	P.
	82·6†	P.	5	58·3*	D.
May 4	77·1	"		60·8†*	P.
9	72·7	W.	10	62·5*	D.
	72·8	B.			

Dark Spot X.

Mar. 10	105·7*	G.	Mar. 29	103·7*	W.
13	110·0†	M.	31	105·3*	"
29	101·6*	P.	Apr. 7	94·0	D.

1898.	λ	Obs.	1898.	λ	Obs.
Apr. 12	92·5	M.	May 18	87·2	M.
16	94·2	D.		92·0	P.
	96·6	P.	June 1	87·6	P.
	97·7	W.		88·0†	W.
19	92·8	P.	10	85·2	P.
	94·3	D.		87·1	D.
23	92·9	"		84·6	G.
	96·3	W.	17	79·7	"
30	85·0	D.		82·7†	M.
	89·3	P.		84·2	D.
	90·1	W.	19	79·6	P.
May 4	90·5	P.	July 3	82·2*	"
9	84·6†	W.		83·8*	D.
11	80·4	P.	5	81·5*	P.
13	83·1	M.	10	78·9†	
16	86·4	D.		80·7*	D.
	86·9	P.			

White Spot XI.

Mar. 22	110·0*	P.	June 10	96·5	D.
Apr. 30	102·1	"		101·7	P.
	103·8	W.	15	104·5†	P.
May 4	102·1†	P.	17	101·0	M.
14	98·9	"		105·2	P.
18	(91·4)	G.		104·9	D.
	98·1	P.	July 3	94·7	"
	97·5	M.	10	91·1†	M.
June 1	97·1	P.		96·6*	D.
	99·0	W.	17	95·8*	"
8	96·7†	M.			

Dark Spot XII.

Feb. 27	121·9*	W.	May 14	108·0	P.
Mar. 20	123·1†	"	16	105·2	D.
22	116·8*	D.		105·2	W.
	118·6*	P.		108·9	P.
31	115·6	W.	18	105·4	"
Apr. 5	112·8	"		107·3	M.
May 14	106·9	D.	June 1	102·6†	P.

1898.	λ	Obs.	1898.	λ	Obs.
June 1	108·2	W.	June 17	113·7*	P.
8	110·7	M.		115·0*	G.
10	110·8	G.		116·9*	M.
	112·1	P.		118·1†*	H.
	114·4†	H.	22	119·8	D.
15	115·5	P.	July 10	105·8*	D.
	116·9	G.		110·0*	M.
17	112·2*	D.			

White Spot XIII.

Mar. 22	122·9*	D.	May 14	112·3*	P.
	126·5*	P.	June 1	111·1*	„
Apr. 16	111·8	W.			

Dark Spot XIV.

Feb. 27	132·8*	W.	May 16	117·4†	M.
Apr. 26	118·4	P.	21	116·6	P.
30	117·3	„	June 1	120·3†*	„
	117·8	W.		120·3†*	W.
May 14	116·0†	P.	July 17	113·4*	D.

White Spot XV.

Mar. 20	134·1*	W.	May 9	123·3	W.
31	127·8*	„	16	121·1	„
Apr. 5	123·2	„	21	126·4	P.
23	124·5	„	June 8	133·9	M.
	127·8	P.	10	128·5*	P.
30	126·5	„	17	132·1*	M.
	128·2	W.	July 10	127·0*	„

Dark Spot XVI.

Mar. 20	143·8*	W.	Apr. 23	134·5	P.
29	139·7*	„	30	136·1	W.
31	139·4*	„		138·7†	P.
Apr. 5	133·6*	„	May 7	124·4	W.
7	127·5*	D.	9	127·6	„
12	121·8	M.	14	132·5†	„
16	127·7	W.	16	130·8	„
21	132·4	„		139·4	M.
23	133·1	„	June 22	135·1†*	P.

White Spot XVII.

898.	λ	Obs.	1898.	λ	Obs.
b. 27	150°·5*	W.	Apr. 23	144°·1	W.
ır. 20	146·6*	P.	30	146·0†	P.
	151·1*	W.		145·9	W.
29	146·1*	P.	May 7	141·5	„
	150·8*	W.	9	142·8†	„
31	150·4	„	12	141·4	D.
r. 1	150·9	M.		144·4	P.
5	145·3	P.	14	143·4	„
	146·4	W.		143·4	D.
12	138·9	M.		146·6	W.
	144·5	P.	16	141·8	M.
	145·0	W.		144·2	W.
	147·4	D.		146·1	P.
16	146·6	W.	21	143·5	„
17	146·6	D.	June 15	141·1	„
19	142·8	P.	22	140·0*	D.
	143·4	D.		142·4*	P.
21	147·0	W.	July 8	140·0*	„
23	143·6	P.	17	138·5*	D.

Dark Spot XVIII.

b. 27	158·4*	W.	Apr. 16	157·6	W.
ar. 13	157·7	P.	17	155·2	D.
20	155·8*	„		157·0	M.
	160·9*	W.	19	154·8	H.
22	159·1	„		154·1	P.
29	157·2	„		156·8	D.
31	158·6	„	21	157·7	W.
pr. 1	155·2	M.	23	157·0	„
	155·8	D.	30	153·2	„
5	153·2	P.		153·3	P.
	155·5	W.	May 7	152·3	W.
7	156·8	D.	12	150·5	D.
8	154·3	„		152·3	P.
12	152·4†	H.	14	152·6†	„
	152·4	P.		154·5	D.
	155·3	D.		154·5	W.
	156·2	W.	16	152·8	P.

1898.	λ	Obs.	1898.	λ	Obs.
May 16	154°0	M.	June 22	150°6*	P.
21	149·6	P.		152·2*	D.
28	156·8	D.	July 8	147·9*	M.
30	(142·8†)	M.		151·0†*	P.
June 8	150·9	,,	10	142·9†	M.
15	147·8	P.	15	152·5*	D.
17	146·7	M.		152·8*	P.

White Spot XIX.

Feb. 27	172·5*	W.	May 14	167·3	W.
Mar. 20	173·7*	,,	30	(154·3)	M.
22	171·2*	,,	June 17	163·8†	,,
Apr. 1	165·0	M.	July 15	161·7*	D.
12	173·6	Bh.			

Dark Spot XX.

Jan. 21	186·7*	B.	May 3	192·0	H.
Feb. 27	185·3*	W.	30	184·2*	M.
Apr. 5	186·1	P.			

Dark Spot XXI.

Mar. 23	213·2*	M.	June 22	192·6*	D.
June 11	194·7*	P.	July 15	183·6*	,,
	199·8*	D.			

White Spot XXII.

Apr. 15	209·6*	D.	Apr. 19	205·0*	W.
17	207·6*	P.	May 12	207·9*	D.
	209·4*	D.	30	201·9*	M.
	209·3*	W.			

Dark Spot XXIII.

Jan. 21	(222·8)	B.	Apr. 19	214·1	W.
Apr. 1	221·0*	P.	22	212·8	M.
15	218·8	D.		217·6	D.
17	215·5*	,,	May 3	215·1	W.
	216·7*	P.	30	212·9	M.
	217·2*	W.	July 13	195·9*	D.

White Spot XXIV.

1898.	λ	Obs.	1898.	λ	Obs.
Apr. 22	220°·1*	M.	June 11	210°·8	D.
24	219·8*	D.		213·6	P.
May 12	213·9	P.	July 13	205·8*	D.

Dark Spot XXV.

Apr. 1	227·2†*	H.	May 12	223·7	D.
17	224·6*	W.	June 4	220·9†	M.
19	223·9*	,,	11	223·0	D.
24	228·1*	H.	July 13	218·5*	,,

White Spot XXVI.

1897. Dec. 22	236·3*	P.	Apr. 5	230·5*	W.
1898. Jan. 21	236·2*	B.	22	228·0	M.
Apr. 1	232·9*	P.	24	230·8*	D.

White Spot XXVII.

Apr. 15	237·6*	D.	Apr. 22	234·1	D.
17	236·3*	P.	24	238·8†	W.
	238·7*	W.	May 3	234·6*	,,

Dark Spot XXVIII.

Apr. 22	243·9*	M.	June 2	235·5†	M.
24	240·6*	D.	25	233·2*	D.

Dark Spot XXIX.

Apr. 1	253·1*	H.	May 3	243·7	W.
15	252·9	W.	19	246·2	M.
24	249·8*	,,	July 2	240·1*	D.

White Spot XXX.

1897. Dec. 20	(291·5)	P.	Apr. 8	269·0	W.
1898. Mar. 5	280·9*†	W.	15	267·5	P.
23	276·7*	P.		268·7	D.
30	(265·0)	M.		268·7	W.
Apr. 1	274·1	P.	17	269·2	P.
4	(266·2†)	M.		270·4	D.
	272·8	D.	22	264·9†	W.
	(265·5†)	W.		268·8	D.

1898.	λ	Obs.	1898.	λ	Obs.
May 3	(252°·3†)	W.	June 2	(248°·3†)	M.
	261·4	,,		254·7	W.
6	265·5	D.		256·2†	P.
	265·5	G.	9	258·4*	D.
15	262·3	D.	11	249·6	P.
	263·8	W.	25	248·5*	D.
24	260·1	,,	July 2	251·1*	,,
26	260·1	M.	4	246·8†	M.

Dark Spot XXXI.

1898.	λ	Obs.	1898.	λ	Obs.
Feb. 21	291·7*	G.	Apr. 17	277·1	P.
Mar. 5	293·1	W.		278·9	D.
7	289·3*	G.	22	277·7	W.
14	282·7*	D.		277·9	D.
	283·9*	H.	May 3	271·8	W.
	285·1*	P.	6	272·8	D.
21	280·4	H.	12	272·4	P.
	283·9	D.	15	272·7	D.
	286·2	W.		273·6	W.
23	284·6	P.	24	274·2	,,
Apr. 1	279·6	,,	26	275·4	M.
2	282·1†	M.	June 2	261·1	,,
4	278·4	,,		267·2	W.
	283·8	D.		269·9	P.
6	280·7	W.	4	261·4	M.
8	282·4	,,	9	268·1	D.
15	276·6	P.		262·3†	P.
	277·9	D.	25	261·9*	D.
	279·7	W.	July 2	260·3*	,,

White Spot XXXII.

1898.	λ	Obs.	1898.	λ	Obs.
Mar. 21	313·1*	W.	May 11	295·3	G.
	314·6*	P.	15	303·2	D.
Apr. 4	295·4	M.	17	296·7	M.
8	297·1*	W.	24	290·6	W.
13	298·8*	,,	31	289·6	P.
	300·0†*	P.	June 2	295·8	M.
15	297·4	,,	9	287·3	P.
	300·4	W.	16	281·4*	,,
17	298·0	,,		282·0*	D.
22	300·3	,,	July 2	273·1*	,,

Dark Spot XXXIII.

1898.	λ	Obs.	1898.	λ	Obs.
Feb. 24	321°·6*	H.	May 15	310°·1†	W.
Mar. 3	326·0*	„		310·5†	P.
14	318·7	D.		312·3	D.
21	319·3	H.	17	312·5	M.
	320·5	D.	24	301·6	W.
	321·0	W.	31	298·2	P.
	324·3	P.	June 2	297·1†	„
28	319·9	„		300·7	M.
Apr. 4	318·0†	M.	7	294·8	D.
6	314·9†	P.	9	297·1*	P.
8	315·4	W.	16	290·5*	„
13	313·4	P.		293·0*	D.
	313·4	W.	July 2	280·1*	P.
16	315·1†	M.		282·2*	D.
22	311·8	W.			

White Spot XXXIV.

Mar. 21	335·1*	W.	June 7	304·6	D.
Apr. 13	329·4*	„		309·9	W.
May 6	319·8	„	9	308·7	P.
17	324·7	M.	16	311·9*	„
31	306·1	P.	30	298·1*	D.
June 2	305·6	„	July 9	285·1	„
5	305·6	B.		294·0†	M.
7	303·8†	M.	16	288·7*	D.

Dark Spot XXXV.

Apr. 2	340·7*	M.	June 9	(328·2)	M.
May 6	328·4	W.	16	318·0	D.
15	331·8	M.	30	313·9*	„
June 2	317·2†	„	July 9	314·9*	„
7	316·8	D.		315·4*	M.
	319·6	W.	16	310·7*	.

White Spot XXXVI.

Mar. 5	344·3*	W.	Mar. 28	346·5	P.
21	345·0*	P.	Apr. 16	349·2	D.
	346·7*	W.	27	343·7	W.

1898.	λ	Obs.	1898.	λ	Obs.
Apr. 29	343°8	P.	June 5	341·4	P.
May 2	341·7	„		342·8	W.
4	341·4	„	7	341·0	M.
6	334·4	D.		342·4	P.
	339·0	P.	12	336·2	D.
	339·3	W.	14	331·3†	M.
9	342·0	B.		334·4	P.
11	347·1	G.	16	336·9	„
15	343·4	M.	30	322·5†	„
	345·2	P.		329·8*	D.
31	(334·7)	„			

Dark Spot XXXVII.

Mar. 5	350·4*	W.	May 15	355·3	P.
21	355·4*	P.	31	347·5	„
	355·2*	W.	June 5	348·1	P.
28	353·8	P.		351·3	W.
Apr. 15	355·9	W.	7	347·1	M.
16	355·2	D.		348·8	P.
22	355·6	„	12	(354·5)	D.
May 2	352·7†	P.	14	346·2*	M.
4	353·6	„		349·0*	P.
6	350·8	„		(355·7)	G.
	350·8	D.	16	347·8†*	P.
15	354·9	M.	21	341·0†	M.

White Spot XXXVIII.

May 6	3·7*	W.	June 14	357·0*	M.
15	2·3*	M.	21	350·2†*	„
29	351·1†	„	July 9	336·1†	„
June 7	353·2	„			

Unused Observations.

Mar. 21	10·0	P.	White	May 13	70·3	M.	White
Apr. 15	10·5	W.	„	18	71·3	„	„
23	79·6	D.	„	27	68·3	„	„
30	71·6	P.	„	Apr. 12	132·6	H.	Dark
	72·8	D.	„		134·3	W.	„
	75·9	P.	Dark		135·8	M.	„

1898.	λ	Obs.	Spot.	1898.	λ	Obs.	Spot.
Apr. 12	167°·0	P.	Dark	May 8	279°·3	G.	White
May 30	169·0	M.		15	282·7	W.	Dark
	176·3	„	White	June 2	277·0	M.	White
June 8	173·5	„	„		278·2	P.	„
Apr. 5	197·6	W.	„	Mar. 5	299·3	H.	Dark
June 22	185·1	D.	„		300·4	W.	„
Apr. 22	232·9	M.	Dark	June 7	328·2	M.	„
May 6	286·9	D.	White	May 31	334·7	P.	White
	287·4	P.	„				

Notes.—Spot I. The bracketed observations relate to the combined mass of I. and XXXVII.

Spot XXIII. It is doubtful if the first observation refers to this spot.

Spot XXX. There were two spots here close together, and the bracketed positions probably relate to the preceding spot. Both spots were observed on May 3.

Spot XXVII. The bracketed observations relate to the combined mass of I. and XXXVII.

Graphical Method for the Determination of the Local Times of Contact in a Solar Eclipse. By F. C. Penrose, D.C.L., F.R.S.

Having first obtained (also graphically) an approximate time for the middle of the eclipse which may be depended upon, if carefully done, within a minute of time, let the reader be supposed to be looking in a southerly direction at a perspective projection, showing the circumstances of the eclipse formed on a plane at right angles to the direction of the Sun and Moon. As he must necessarily be rather nearer to the Moon than the geocentric distance, the *distance of the picture* would be somewhat less than the geocentric distance, and her semi-diameter and the other lunar elements would be augmented; but for convenience of calculation it is better to use the geocentric values, which would have the same relation to one another in projection, and to reduce the solar in inverse proportion. This need only be done to the semi-diameter, which is the only one of consequence.

In this projection the parallax which represents the observer's motion will be an arc of an ellipse dependent upon horizontal parallax and geocentric latitude; and the soli-lunar motion, as the arc is so small, admits of being represented by a straight line.

This being premised, the elements for constructing a diagram to show the circumstances of totality may be thus found.

First, compare the arguments given for the Sun and for H.P. and the Moon's semi-diameter in the *Nautical Almanac* for the same day at noon (unless, owing to longitude or other considera-

tions, a midnight argument, or one for another noon would be nearer to the assumed time) with those given for the particular eclipse, and tabulate the differences ; then find from these the corrections required for the assumed time in simple proportion, giving for the assumed time the R.A. and declination of the Sun, the H.P. and the Moon's semi-diameter. Then find the hour angle, and with the geocentric latitude compute the values in the direction of R.A. and declination of the parallax, the tangent to the elliptic curve, and the extent of one minute's motion and the Sun's altitude, and from this compute the augmentation. We are now in a position to lay down on paper two straight lines, one representing the soli-lunar motion to be drawn through the place as above found for the solar and lunar centres, and the other representing the tangent to the parallactic curve drawn through the corresponding point of parallax. Mark on these lines the extent of one minute's motion, both previous to and subsequent to the assumed time, produced as might be required, and subdivided into scales of seconds of time.

It is now easy, if totality be possible, to find the points where the extremities of a radius $= S - s$ with its augmentation increment, will rest upon similar numbers of seconds on the soli-lunar and parallax scales, the western coincidence giving the second and the eastern the third contact.

Calculation of the times of 2nd and 3rd Contact for the Total Solar Eclipse at Ovar on 1900 May 28.

Latitude of Ovar $= \lambda = 40^\circ\ 51'$ N.

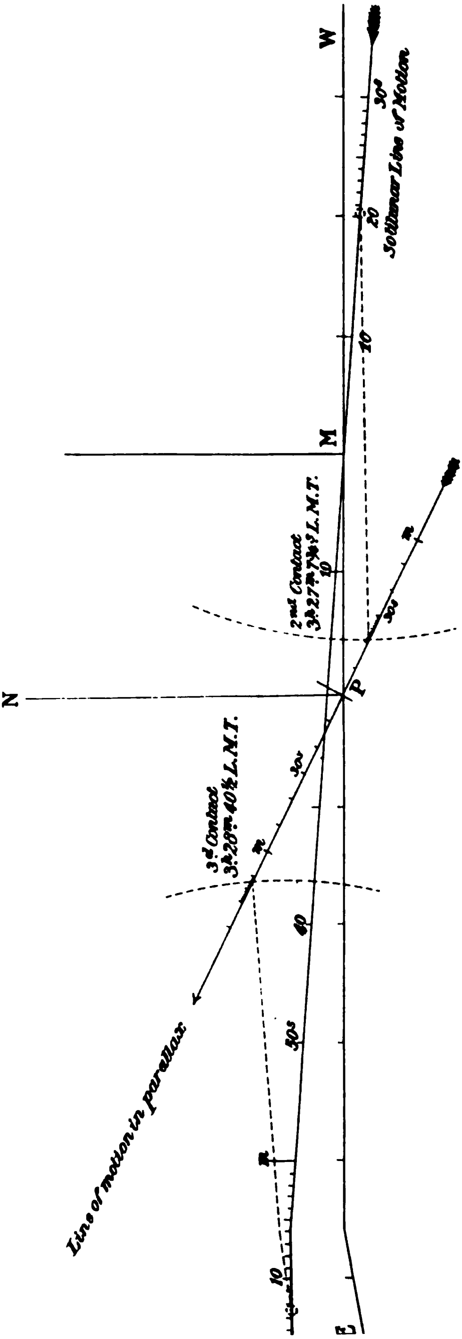
Geocentric Latitude $= l \begin{cases} \log \rho \sin l = 9{\cdot}81330 \\ \log \rho \cos l = 9{\cdot}87940 \end{cases}$

Longitude of Ovar $= 34^m\ 32^s$ W.

Mid-totality at Ovar occurs at $4^h\ 2^m$ G.M.T. (approx.)

1900 May 28, $4^h\ 2^m$ G.M.T.

☉'s R.A.	$= a = 4^h\ 19^m\ 58^s{\cdot}33.$	Change in $1^m = 0^s{\cdot}178$	
☉'s Dec.	$= \delta = 21^\circ\ 27'\ 41''{\cdot}9.$	,, ,, $= 0''{\cdot}405$	
Hour Angle	$= t = 3^h\ 30^m\ 26^s{\cdot}45$ E.		
Altitude of ☉	$= 41^\circ\ 49'{\cdot}5$		
☽'s R.A.	$= A = 4^h\ 22^m\ 28^s{\cdot}76.$	Change in $1^m = 2^s{\cdot}484$	
☽'s Dec.	$= D = 21^\circ\ 53'\ 6''{\cdot}36.$	,, ,, $= 2''{\cdot}529$	
☽'s Hor. Par.	$= P = 58'\ 25''{\cdot}79$	$P - p = 58'\ 17''{\cdot}06$	
☉'s Hor. Par.	$= p = 8''{\cdot}73$		
☽'s Semi-diam.	$= S = 15'\ 55''{\cdot}30$	$S - s = 8''{\cdot}71$	
☉'s Semi-diam.	$= s = 15'\ 46''{\cdot}49$		



CIRCUMSTANCES OF THE TOTAL ECLIPSE AT OVAR
REDUCED GRAPHICALLY

The augmentation of $S-s$ for Altitude $41^\circ\ 49'\cdot5 = 10''\cdot80$

$\therefore$ The augmented value of $S-s = 19''\cdot51$

The Parallax in R.A. $= (P-p)\ \rho \cos l \sin t$

$= 35'\ 4''\cdot75$

The Parallax in Dec. $= (P-p)\ (\rho \sin l \cos \delta - \rho \cos l \sin \delta \cos t)$

$= 25'\ 28''\cdot69$ (above the centre)

The Soli-lunar position in R.A. $= (A-a) \cos D$

$= 34'\ 53''\cdot85$ (E. of Minor Axis of parallactic ellipse)

" " " in Dec. $= D - \delta$

$= 25'\ 24''\cdot46.$

To this $4''\cdot20$ must be added, on account of the lunar orbit, making the position $25'\ 28''\cdot66$ above the centre.

The extent of motion of parallax in 1^m in R.A.

$$= (P-p)\ \rho \cos l \cos t\ \Delta t = 7''\cdot02.$$

The extent in Dec. $= (P-p)\ \rho \cos l \sin \delta \sin t\ \Delta t.$

Therefore the tangent of the angle at the parallax point

$$= \sin \delta \tan t = 25^\circ\ 35'.$$

The Soli-lunar motion in R.A. in $1^m = (2^s\cdot484 - 0^s\cdot178) \cos \delta$

$= 32''\cdot24$

" " " in Dec. in $1^m = 2''\cdot529 - 0''\cdot405$

$= 2''\cdot124.$

The diagram (Plate 14) is constructed from these elements: P is the parallax at $4^h\ 2^m$ and its line of motion is drawn. M is the Soli-lunar centre and its line of motion is drawn. The diagram shows that the second contact occurs $20^s\tfrac{1}{4}$ before $4^h\ 2^m$, and the third contact $1^m\ 12^s\tfrac{1}{2}$ after it.

An Application of Projective Geometry to Binary Star Orbits.
By H. C. Plummer.

1. In the numerous methods which have been employed in the determination of the orbits of double stars, it is natural, on account of the comparatively coarse nature of the observations, that much use has been made of graphical devices. These for the most part are of the "trial and error" kind. T. N. Thiele* and J. M. Wilson,† however, have given direct geometrical constructions by which the relations between the apparent and the

* *A.N.* 1227. † *M.N.* xxxiii. p. 375.

real orbit are exhibited, and the former has made practical use of his method. It is my object here to deduce these relations from a consideration of the projective properties of the ellipse, and to show how the geometrical elements of the orbit, viz. i, Ω, λ, e, a, may be determined by a tolerably simple construction. It is, of course, impossible to use direct time measures in a method which is essentially geometrical. As in Savary's* first method, the necessary data are taken in the shape of five positions in the apparent orbit. Then the problem to be solved may be stated thus: Given five points and a certain fixed point, to find the orthogonal projection such that the corresponding five points will lie on an ellipse the focus of which projects into the fixed point. The solution takes the form of constructing the line of nodes, finding the inclination of the orbit, and laying down the five points corresponding to the apparent positions. The ruler and compasses alone are used in the process, and it is quite unnecessary to draw an ellipse.

2. It is convenient to consider in the first place a fundamental problem the solution of which will be required. This is to find the orthogonal projection by which two right angles project into two given overlapping angles contained by four lines which meet in a point. Let S be the point (Plate 15, fig. 1), and suppose that the lines intersect a transversal in AA′, BB′. On AA′, BB′ as diameters describe circles meeting in a point F. Then if F be rotated about AA′ out of the plane of the paper, the given figure may be considered as a projection on to the plane SAA′ from the point at infinity on the line SF as vertex. The projection is a parallel one, and is in addition orthogonal if SF be perpendicular to the plane SAA′. Hence SF must be perpendicular to AA′. Now if N is the foot of the perpendicular from F on AA′, $AN.NA' = NF^2 = BN.NB'$, or N is the centre of the involution range determined by AA′, BB′. Hence SN and the line through S parallel to AA′ are a corresponding pair of the involution pencil S (AA′, BB′,...), since N being the centre of the range is the point corresponding to the point at infinity on AA′. Conversely if the transversal AA′ be drawn parallel to one line of the orthogonal pair in the involution pencil S (AA′, BB′...), the point F constructed as above will lie on the perpendicular from S to the transversal. Then when F is rotated about AA′ till FS is perpendicular to the plane SAA′, the projection is orthogonal, and we have the projection required, for the angles ASA′, BSB′ are the projections respectively of AFA′, BFB′, which being angles in semicircles are right angles. We thus have a simple method suggested for constructing the transversal or turning line AA′ through any fixed point C, which is as follows. Describe a circle on SC as diameter and let it cut the rays of the pencil S (AA′, BB′) in A_1, A_1', B_1, B_1'. Join OK, where K is the centre of the circle and O is the intersection of

* *Conn. des Temps*, 1830.

Fig. 1

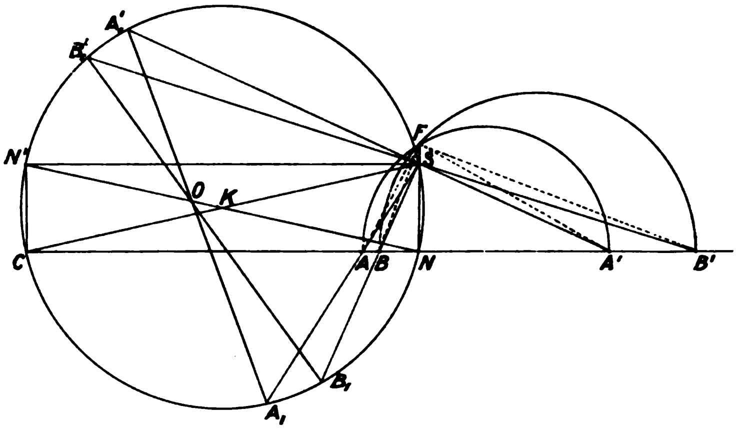
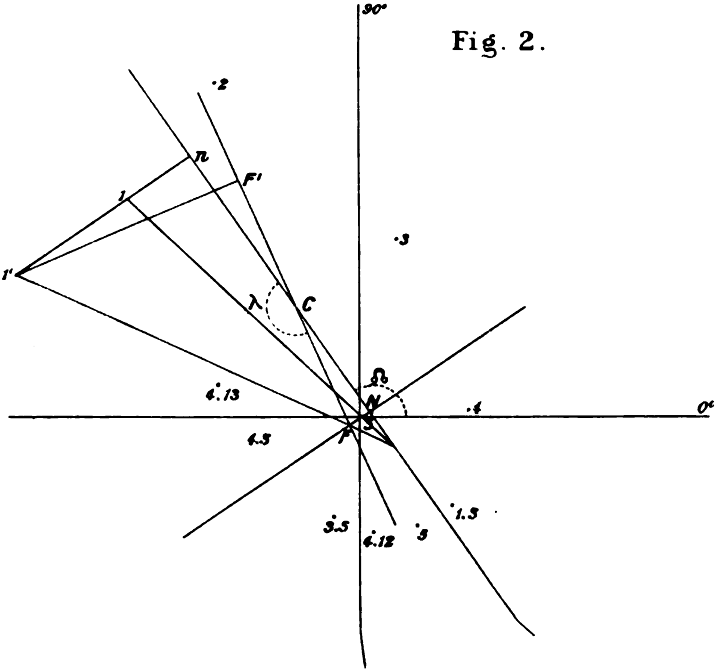


Fig. 2.



A_1A_1' and B_1B_1', and let OK meet the circle in NN′. Then SN, SN′ are orthogonal rays of the involution, since NN′ is a diameter and NN′, A_1A_1', B_1B_1' are concurrent chords. Also clearly CN, CN′ are parallel to SN′, SN respectively. Finally the choice between CN and CN′ as a transversal must be decided by the consideration that it must fall across the obtuse angle between SA and SA′, for otherwise the point F would lie nearer the turning line than S, and the orthogonal projection would become impossible.

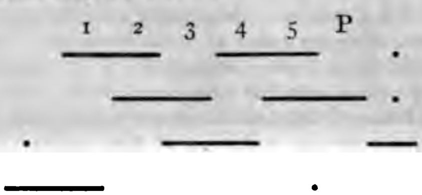
3. The general method of procedure is now obvious. Through S, the position of the principal star, two pairs of conjugate lines must be drawn. If then through C, the centre of the apparent ellipse, a line be drawn by the construction given at the end of § 2 parallel to one of the orthogonal pair of the involution of conjugate lines through S, this line is the turning line required, or the line of nodes. Then the point F is found as in § 2, and this when the plane FAA′ is rotated so that FS is perpendicular to the plane SAA′ projects orthogonally into the point S. Moreover, since the conjugate pairs of lines through S are the projections of orthogonal pairs through F, F is the focus of the ellipse which projects into the apparent orbit. As the line of nodes and the focus of the true orbit are now known, the problem in view has been virtually solved. If the method of Sir John Herschel has been followed as far as the drawing of the apparent ellipse, the centre C is known and pairs of conjugate lines may be constructed by drawing chords through S, constructing tangents to the ellipse at their extremities and joining S to the poles of the chords. The completion of the solution is then simple and rapid.

4. But the actual drawing of the apparent orbit is unnecessary and even objectionable. For it must be a more or less troublesome and unsatisfactory process, and besides the choice of five characteristic points should be not merely easier but also capable of at least equivalent accuracy. Hitherto observed distances have been utilised only in a minor degree in the calculation of orbits, having been long under the ban of Sir John Herschel's authority. Even at the time when this neglect may have been justified by the inferiority in the measures of this coordinate, Encke held other views as to their value. But now that greatly increased accuracy is attainable in this part of the observations, it seems permissible to place reliance on this material, and perfectly feasible to employ it for the purpose we have in view.

The five points will be denoted by the numbers 1, 2, 3, 4, 5 (Plate 15, fig. 2). Also the other extremity of the chord through 1 parallel to the line joining 2 and 3, for instance, will be denoted by the notation 1.23, while the other extremity of the chord through 1 and S will be denoted by 1.S. Now points such as 1.23 and 1.S can be easily found by the well known construction with the ruler only. Five of these points are required, two of the former type and three of the latter. The two will determine two pairs

of parallel chords, and will therefore give the centre of the ellipse as the intersection of the two diameters which bisect the parallel chords. The other three points give three chords which meet in S, and by taking these two at a time we obtain three quadrangles inscribed in the conic, for each of which S is a harmonic point. Thus, for instance, if the quadrangle 1, 2, 1.S, 2.S, be taken, and the lines joining 1, 2 and 1.S, 2.S, meet in Z, while the lines joining 1, 2.S and 2, 1.S meet in Z′, the pair of lines SZ, SZ′ are conjugate. Three pairs of conjugate lines can therefore be drawn, and as two only are required those may be chosen which can be constructed most easily.

5. The construction of the five additional points is an important part of the method, and as it is rather complicated I give the following plan which I have found a convenient aid in order to avoid confusion. Suppose that the point P is required in which a fixed line through 5 cuts the ellipse again. Then the following scheme may be useful :—



in which each line indicates that the points to be found vertically above it are to be joined, and which is to be taken line by line, and read thus: (1) join 1, 2 and 4, 5; these meet in a point (placed on the right); (2) join 2, 3 which meets the line 5P in a point (also placed on the right); (3) join 3, 4 and the two points of intersection; these lines meet in a point (placed on the left); (4) join the latter point to 1, and this line intersects 5P in the point required. The scheme can be followed mentally on the figure before the construction is made. In this way it can be decided first whether the intersections will fall conveniently on the paper. If, as will often happen, they fall outside it, it will be better to alter the order of the first four points in the scheme. There will then be a new hexagon, and the Pascal line may be constructed more easily. For instance, if the intersection of 12 with 45 is near the centre of the paper, and the intersection of 23 with 5P lies beyond the edge, it is natural to start with the hexagon 2 1 3 4 5 P instead of 1 2 3 4 5 P. Such details will naturally occur, and are only mentioned here because they have considerable importance in practice.

6. For the sake of clearness it seems well to summarise the actual steps which have to be made, referring for greater definiteness to an actual case. The natural order will be :

(*a*) To select the characteristic positions and to plot the five places to a suitable scale.

(*b*) To construct the points 4.12 and 4.13, to draw the diameters bisecting the parallel chords, and so to find the centre C.

(*c*) To construct the points 1.S, 3.S, and 4.S, to complete the quadrangles 1, 4, 1.S, 4.S, and 3, 4, 3.S, 4.S, and by means of them to draw two pairs of conjugate lines through S.

(*d*) To construct, as explained in § 2, the orthogonal pair of the conjugate involution, and to draw through the centre the line of nodes.

(*e*) To find the point F as in § 2; this is the focus of the real orbit. Also it is evident that the inclination is given by

$$\cos i = \mathrm{SN}/\mathrm{FN}.$$

(*f*) To lay down the five positions in the real orbit, and to deduce the values of the elements a, e and λ. This will be next explained.

7. In the first place CF is the line of apsides, and CN is the line of nodes; it follows that $\pi - \lambda$ is the angle FCN As the relations between the planes of the apparent and real orbits have been already found, it is unnecessary to retain the distinction. In fact it is simpler to lay down the five real positions in the plane of the paper by considering them as in parallel homology with the apparent figure. The line of nodes CN is the axis of homology, the centre of homology is at infinity on a line at right angles to CN, and F and S are a pair of corresponding points. The point 1′ corresponding to 1 is then easily found, since 11′ is perpendicular to CN, and 1′F and 1S meet on CN. Similarly the homologues of the points 2, 3, 4, 5 can be laid down. Then if F′ be the second focus, five measures of a are available, viz. $\frac{1}{2}$ (1′F + 1′F′), &c. But CF $= ae$, and so the eccentricity is found by dividing CF by the mean value of a. Thus all the geometrical elements of the orbit have been found, and finally the two remaining elements, the mean motion and the epoch, can be calculated at once from the dates of two observations, though of course better from more extensive data. It is to be remarked that the agreement in the values of a, found as above from the five points, is a measure of the correctness of the drawing, on which it forms a useful check. On the other hand, additional normal places may be laid down, and their homologues may be constructed. From these an additional set of values of a can be obtained. The agreement of these values among themselves, and with the former set, furnishes a criterion of the concordance of the observations involved, and of the accuracy of the assumption that the five adopted positions characterise the orbit.

8. Having now sketched a method of dealing with binary star orbits, it is interesting to consider the result of applying it to a particular system. In order best to test the practicability of the method and to judge the order of accuracy which it is capable of giving, I chose the star 70 *Ophiuchi*, because, apart from the

historic interest which the system possesses, and the fact that sufficient observations existed to make a fair trial possible, it has been made the subject of an exhaustive research by Professor Schur, and therefore its orbit is to be considered so far definitive as the refinements of rigorous calculation could render it. The five characteristic places were chosen at random, but so as to cover as large an arc as possible, though it was judged advisable to leave on one side the earlier observations of Sir W. Herschel and others. The following are taken from a list of normal places given by Dr. See * :—

No.	Date.	Pos. Ang.	Dist.
1	1830·57	136°·8	5″·58
2	1854·48	113·2	6·37
3	1877·60	77·4	3·23
4	1887·68	3·8	1·91
5	1895·64	296·1	2·14

These were plotted to the scale 1″=22 mm., and their relative positions are quite roughly indicated in fig. 2. The result of measuring the drawing was to give the following elements, against which I place Professor Schur's † elements for comparison :—

		Schur.
i	57° 40′	60°·08
☊	121 49	121·31
λ	167 2	168·3
a	4″·596	4″·60
e	·515	·4751

The value of a given above rests on a single measure of F1′+F′1′. This in itself is an indication that the above elements are really what might not unfairly be called a rough preliminary measurement, the apparent accuracy being altogether unexpected and surprising. They represent such results as may reasonably be attained in an hour's work after the five points have been selected and laid down.

9. It then became a matter of interest to calculate the epoch and the mean motion. Using the extreme places 1 and 5, we get these values :—

		Schur.
T	1895·445	1896·4661
P	86·8	88·3954

Instead of proceeding with these, which evidently rest on an insufficient basis, it seemed better to use additional places, and the following elements were adopted, though it must be under-

* *Ast. Jour.* 363. † *A.N.* 3220–1.

tood that they were not obtained, as they might have been, from least squares solution :—

$$T=1895{\cdot}70, \quad P=88{\cdot}32, \quad a=4''{\cdot}495.$$

'he following table exhibits the comparison between the places omputed from these elements and the observed coordinates, 'hich have been taken from Dr. See's paper already quoted, xcept the last three places depending solely on Mr. Maw's ieasures.*

e.	Position Angle.	Distance.	C−O Angle.	C−O Distance.
	°	"	°	"
57	136·8	5·58	−1·3	−0·27
58	135·1	5·68	−0·9	−0·18
62	133·4	5·75	−0·5	−0·09
42	132·8	6·14	−0·9	−0·37
55	130·8	6·04	−0·1	−0·12
60	130·7	6·11	−1·1	−0·06
52	128·9	6·34	−0·2	−0·20
64	127·9	6·45	−0·3	−0·19
59	126·6	6·64	0·0	−0·29
58	125·5	6·66	+0·2	−0·24
47	126·5	6·38	−1·7	+0·11
64	124·0	6·60	−0·2	−0·04
57	123·8	6·57	−0·9	+0·06
60	123·5	6·79	−0·6	−0·18
55	122·1	6·57	+0·1	+0·10
44	121·3	6·66	+0·1	+0·02
48	120·9	6·64	−0·3	+0·07
46	119·3	6·76	+0·4	−0·01
47	119·1	6·85	−0·3	−0·11
38	118·4	6·81	−0·3	−0·06
39	118·1	6·64	−0·8	+0·10
55	116·4	6·78	−0·1	−0·06
54	115·5	6·57	0·0	+0·11
59	114·9	6·56	−0·4	+0·09
57	114·9	6·42	−1·1	+0·19
48	113·2	6·37	−0·3	+0·20
52	113·3	6·45	−1·3	+0·06
43	111·7	6·34	−0·5	+0·10
52	111·0	6·31	−0·8	+0·07

Date.	Position Angle.	Distance.	C−O Angle.	C−O Distance.
	°	"	°	"
1858·39	109·1	6·01	+0·3	+0·29
1859·66	108·4	6·24	−0·3	−0·05
1860·70	107·3	6·33	−0·2	−0·24
1861·67	106·2	5·70	−0·1	+0·20
1862·59	105·6	5·83	−0·4	+0·05
1863·54	104·8	5·62	−0·6	+0·14
1864·54	104·1	5·43	−1·0	+0·20
1865·50	102·4	5·32	−0·5	+0·18
1866·43	101·2	5·31	−0·6	+0·06
1867·50	99·6	5·18	−0·5	+0·03
1868·65	98·6	4·90	−1·1	+0·14
1869·80	96·7	4·64	−1·0	+0·21
1870·51	94·2	4·52	+0·3	+0·20
1871·56	93·4	4·34	−0·6	+0·19
1872·51	91·6	4·20	−0·7	+0·16
1873·56	88·1	4·01	+0·7	+0·15
1874·61	87·7	3·81	−1·4	+0·14
1875·61	84·2	3·59	−0·5	+0·15
1876·57	80·7	3·48	+0·3	+0·06
1877·60	77·4	3·23	+0·4	+0·08
1878·58	74·3	3·05	0·0	+0·05
1879·57	69·5	2·95	+0·8	−0·05
1880·59	64·0	2·64	+1·4	+0·04
1881·56	60·3	2·55	−0·3	−0·05
1882·60	52·5	2·48	+0·9	−0·17
1883·62	44·0	2·31	+2·0	−0·16
1884·56	36·0	2·17	+2·3	−0·13
1885·61	25·9	2·06	+2·6	−0·12
1886·61	14·3	1·93	+4·1	−0·01

* *Mem. R.A.S.* liii.

Date.	Position Angle.	Distance.	C–O Angle.	C–O Distance.	Date.	Position Angle.	Distance.	C–O Angle.	C–O Distance.
	°	″	°	″		°	″	°	″
1887·68	3·8	1·91	+2·8	−0·01	1894·69	304·2	2·30	−0·7	−0·09
1888·62	353·9	2·11	+2·5	−0·21	1895·32	298·6	2·22	−0·1	−0·05
1889·53	345·9	2·08	+1·1	−0·10	1895·64	296·1	2·14	−0·1	+0·02
1890·57	336·7	2·21	+0·2	−0·17	1896·61	289·0	2·31	−1·3	−0·26
1891·59	327·4	2·23	+0·7	−0·11	1897·55	279·7	1·80	−1·0	+0·10
1892·52	320·8	2·26	−0·2	−0·09	1898·55	270·7	1·91	−2·4	−0·07
1893·62	312·9	2·25	−1·2	−0·05					

The fact must be insisted on that no endeavour has been made to give a definitive orbit to 70 *Ophiuchi*, and nothing more has been attempted than to give a practical illustration of the working of the general method. Herein lies the justification for the merely rough adjustment of the elements T, P, and a. The other elements used are those given above, and as regards these an improved value might probably be assigned to the inclination. The value given rests on the measurement SN=6·15 mm., FN=11·5 mm. Greater relative accuracy can be attained in the measurement of longer lines, and it is therefore better to rely on the equivalent ratio $1n/1'n$ (fig. 2), for which, on reference to the original drawing, I find $1n=31·3$ mm., $1'n=60·0$ mm. These measurements give

$$i=58°33'.$$

1900 *April* 10.

On the Orbit of β 883. By T. Lewis.

The uncertainty in the period of this double star arises in the first instance from the difficulty in fixing the proper quadrant owing to the components being of nearly equal magnitude; and secondly, by reason of their closeness, the distance between the two stars never exceeding 0″·3.

Dr. See has assigned a period of 5½ years, which makes β 883 the most rapid binary known. On the other hand, Professor Glasenapp's period of 16·8 years would merely rank it amongst the most rapid pairs.

Since 1896 this star has been under almost continuous observation, and hence the area swept out during these four years may be taken as a standard area affected with but small error. Working backwards with this argument, it became at once evident that Burnham's measure in 1891·97 really belonged to the third quadrant. Admitting this, we must place the observations of 1894 and 1895 in the opposite quadrants set down by the observer. These are all the changes requisite, and are shown in the following means by brackets:—

Weight.
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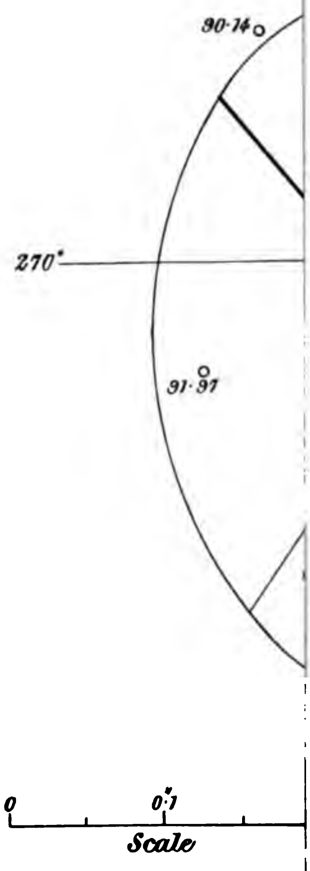

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Date.	Position Angle.
1887·68	3 8
1888·62	353 9
1889·53	345·9
1890·57	336·7
1891·59	327·4
1892·52	320·8
1893·62	312·9

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Date.	Angle.	Distance.	Observers.	Weight.
1879·00	17·5°	0·35″	Burnham	1
87·15	84·7	0·15	Schiaparelli	3
88·06	124·4	0·18	Schiaparelli	2
89·14	158·5	0·20	Schiaparelli	4
90·14	203·4	0·16	Schiaparelli	3
91·14	Single		Burnham	2
91·15	Single		Schiaparelli	7
91·97	[123·1]	0·12	Burnham	3
93·12	Single		Schiaparelli	2
94·66	[176·4]	0·19	Barnard	3
95·86	[188·4]	0·29	See, Schiaparelli	
97·01	24·9	0·28	Burnham, Bryant	
97·60	34·5	0·29	Barnard, Bowyer	
98·03	37·6	0·30	Brown, See	
98·80	46·9	0·28	Hussey, Dyson	
99·15	51·1	0·27	Schiaparelli	
1899·83	56·2	0·26	Cogshall, Lewis	
1900·16	62·3	0·25		

The numerals show the number of nights of observation which in the later groups range from 15 to 20.

The apparent orbit finally adopted is shown on Plate 16, with the above places plotted down. The dark line represents the projected major axis, and is so placed that the period and periastron may be easily checked.

The features of the adopted orbit are—

(1) The few changes of quadrant necessary.
(2) The inclusion of the negative results of 1891.
(3) The attempt to satisfy the original measure of 1879.

This observation is affected by an error of some kind, and would look better as $-17°·5$. This is, however, of no great importance, the object being to decide between a $5\frac{1}{2}$-year period and one roughly three times this value.

The elements are :

T	1890·6	☊	177° 6′
P	15·8 years	λ	49° 4′
e	·359	γ	41° 18′
a	0″·24		

1900 *March* 20.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the year 1899.

(*Communicated by the Astronomer Royal.*)

The measures were made with a bifilar position-micrometer on the 28-inch refractor, aperture 28 inches, focal length 28 feet. The power generally used was 670, but when the definition permitted, a power of 1030 was used for observing very close pairs. A blue shade was used to diminish the light and irradiation when bright stars were observed. The observations were made in variously coloured fields, or in a dark field with illuminated wires.

Altogether 563 pairs have been measured, of which 130 are less than 0″·5 apart, 124 are between 0″·5 and 1″·0, 126 between 1″·0 and 2″·0, 80 between 2″·0 and 3″·0, and 103 over 3″·0. The majority of the last group are stars with very faint companions, such as *Aldebaran*, *β Cygni*, and *β Aquilæ*.

The initials in the last column are those of the observers, viz.—D., Mr. Dyson; C., Mr. Cowell; L., Mr. Lewis; B., Mr. Bryant; W. B., Mr. Bowyer; and P. M., Mr. Melotte.

Micrometric Observations of Double Stars.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
Krueger 1 ...	0 6	32 43	194·6	2·00	1	9·1 9·2	·011	B.
OΣ 2 ...	0 8	63 35	37·1	0·47	1	6·5 8·0	·852	W.B.
β 864 ...	0 8	55 12	149·4	2·02	1	8·6 11·9	·893	L.
β 1015 ...	0 14	78 16	122·5	0·45	1	8·2 8·3	·905	W.B.
β 1093 ...	0 15	73 36	62·6	0·42	1	7·3 8·2	·906	W.B.
OΣ 12 ...	0 26	36 8	149·7	0·36	1	5·0 6·0	·011	B.
β 865 ...	0 39	47 20	196·9	1·34	1	8·4 8·9	·011	B.
β 866 ...	0 40	47 20	74·8	1·44	1	9·1 9·1	·011	B.
β 495 ...	0 42	71 52	222·5	0·47	2	7·6 7·7	·868	W.B.
Σ 60 (η Cassiopeiæ)	0 42	32 44	219·9	5·21	1	4·0 7·6	·011	B.
OΣ 20 ...	0 49	71 22	321·8	0·43	1	5·9 7·0	·906	W.B.
Σ 73 (36 Andromedæ)	0 49	66 55	16·9	0·93	2	6·2 6·8	·868	W.B.
Σ 79 ...	0 54	45 44	191·7	7·88	1	6·0 7·0	·068	B.
β 303 ...	1 4	66 44	283·8	0·54	1	7·2 7·5	·906	W.B.
Σ 97 ...	1 6	48 59	101·8	4·51	1	8·5 8·7	·068	B.
Σ 122 ...	1 22	86 59	327·1	6·02	1	7·9 9·0	·063	W.B.
			329·7	6·04	1	...	·066	L.
			327·7	5·89	1	...	·068	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
β 1164 ...	1 22	84 10	174·0	0·31	1	6·7 7·0	·025	B.
Σ 135 ...	1 28	54 18	219·1	1·53	1	8·9 10·7	·011	B.
β 507 ...	1 30	63 44	157·0	2·21	1	8·0 11·0	·846	L.
Σ 138 ...	1 30	82 52	219·1	1·53	1	7·3 7·3	·011	B.
Σ 141 ...	1 35	51 32	299·7	1·50	1	8·0 8·5	·063	W.B.
			303·1	1·96	1	...	·068	B.
Σ 157 ...	1 41	51 34	193·9	1·02	1	8·5 8·7	·071	L.
A.C.	...	...	116·0	12·35	1	8·5 11·0	·071	L.
Σ 158 ...	1 41	57 20	262·6	1·86	1	8·3 8·8	·011	B.
			259·9	2·03	1	...	·140	W.B.
			259·3	1·86	1	...	·549	L
β 1016 ...	1 44	57 25	209·0	0·60	1	8·5 8·5	·068	B.
			210·6	0·64	1	...	·140	W.B.
			211·6	0·55	3	...	·460	L.
Hough. 311	1 45	65 50	178·3	0·43	1	7·5 7·7	·906	W.B.
Σ 183 A.B.	1 49	61 41	357·7	0·44	1	7·5 8·2	·011	B.
			358·9	0·52	5	...	·480	L.
			358·6	0·47	2	...	·523	W.B.
A.C.	...	...	162·2	5·12	1	7·5 8·9	·011	B.
			160·9	5·55	4	...	·480	L.
			161·2	5·32	2	...	·523	W.B.
Σ 189 ...	1 52	71 32	266·6	8·84	1	8·7 9·8	·063	W.B.
			269·0	9·00	1	...	·068	B.
OΣ 38 (γ Andromedæ)	1 58	48 10	116·3	0·31	4	5·0 6·2	·663	L.
Σ 208 ...	1 58	64 33	64·5	0·46	1	6·2 8·4	·011	B.
Hough. 497	2 6	53 7	66·3	0·51	1	8·2 9·0	·909	L.
Σ 228 ...	2 8	42 59	81·1	0·34	1	6·7 7·6	·068	B.
			80·0	0·43	1	...	·827	L.
Σ 258 ...	2 18	56 57	29·0	5·88	1	7·7 8·9	·071	L.
OΣ 44 ...	2 36	47 44	50·2	1·34	1	7·8 8·5	·011	B.
			55·7	1·29	1	...	·140	W.B.
β 262 ...	2 41	59 22	56·4	1·63	1	8·2 9·6	·071	L.
Σ 305 ...	2 42	71 2	314·8	2·85	2	7·3 8·2	·024	B.
β 524 ...	2 47	52 5	29·5	elong.	1	5·5 6·5	·071	L.
			19·7	0·16	1	...	·909	L.
β 525 ...	2 53	52 31	131·3	0·33	1	7·5 7·5	·036	B.
			132·6	0·16	2	...	·152	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
Σ 333 (ε Arietis)	2 53	69 4	198·8	1·44	2	5·7 6·0	·025	B.
			202·5	1·18	2	...	·533	L.
Σ 346 A.B.	2 59	65 8	91·5	0·42	1	6·0 6·0	·909	L.
A.C.	...	...	359·7	5·23	1	...	·909	L.
β 1030 ...	3 4	68 39	168·2	0·39	1	8·4 8·4	·090	B.
			157·1	0·46	3	...	·405	L.
β 530 ...	3 8	67 25	194·2	1·99	2	9·7 10·1	·153	L.
β 878 ...	3 22	67 32	83·7	0·97	1	5·8 13·0	·156	L.
Σ 412 (7 Tauri)	3 28	65 52	5·0	0·22	2	6·6 6·7	·529	L.
Σ 410 ...	3 29	58 19	205·7	11·64	1	7·8 11·8	·909	L.
β 533 ...	3 29	58 39	50·5	0·64	...	7·0 7·0	·269	L.
β 535 ...	3 38	58 2	50·8	1·00	1	3·8 8·5	·171	L.
Σ 439 A.C.	3 38	58 9	39·6	24·00	1	8·7 9·1	·102	L.
β 880 A.B.	...	...	353·2	0·49	4	8·7 8·9	·085	L.
			360·2	0·39	2	...	·123	B.
β 1184 ...	3 42	67 56	263·3	0·48	1	8·1 8·3	·011	B.
			276·3	0·65	1	...	·148	L.
β 536 A.B.	3 40	66 6	298·5	elong.	1	8·3 8·9	·149	L.
C.D.	...	...	10·1	18·71	1	8·0 12·0	·149	L.
Σ 471 (ε Persei)	3 51	50 17	7·8	8·81	1	3·1 8·3	·200	L.
OΣ 531 ...	4 0	52 12	129·2	1·82	1	8·5 10·2	·113	W.B.
			129·1	1·71	1	...	·129	L.
β 1232 ...	4 2	61 6	352·8	0·39	1	8·5 9·5	·150	L.
Hough. 326	4 2	61 40	172·4	0·36	2	8·5 8·5	·150	L.
			175·1	0·19	1	...	·197	B.
OΣ 77 ...	4 9	58 34	166·1	0·24	3	7·0 7·5	·096	L.
			143·0	0·15	1	...	·197	B.
OΣ 79 ...	4 14	73 45	61·5	0·39	1	6·4 7·6	·068	B.
OΣ 80 ...	4 17	47 46	184·8	0·63	1	6·5 7·0	·068	B.
			181·2	0·56	2	...	·182	L.
Σ 535 ...	4 17	78 53	327·3	1·51	2	6·7 8·2	·030	B.
			323·7	1·70	2	...	·510	W.B.
OΣ 82 ...	4 18	75 12	129·3	0·59	1	8·0 8·7	·040	B.
			128·3	0·36	1	...	·063	W.B.
			123·8	0·51	1	...	·947	L.
β 1235 ...	4 18	67 29	60·6	0·31	2	8·4 8·5	·556	L.
β 745 ...	4 19	36 7	136·0	0·70	1	8·3 8·3	·203	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
Hastings ...	4 30	70 29	54·8	0·36	1	8·0 9·0	·071	L.
			53·5	0·48	1	...	·142	W.B.
β 550 (Aldebaran) A.B.	4 30	73 42	110·8	31·08	3	1 14	·144	L.
β 1031 (Aldebaran) C.D.	...	...	277·2	2·01	2	10½ 13½	·103	L.
OΣ 86 ...	4 31	70 27	58·7	0·46	1	7·5 7·5	·011	L.
			58·8	0·49	1	...	·068	B.
Σ 567 ...	4 31	70 44	323·5	1·98	1	8·5 9·0	·025	B.
			320·4	1·89	1	...	·063	W.B.
			322·7	2·17	1	...	·071	L.
Σ 572 ...	4 32	63 16	203·0	3·61	1	6·5 6·5	·036	B.
			202·1	3·08	1	...	·036	C.
			199·7	3·65	1	...	·142	W.B.
* ...	4 34	63 16	213·4	0·82	1	8·0 9·0	·151	L.*
β 883 ...	4 45	79 6	49·8	0·36	5	7·5 13·0	·097	L.
			48·8	0·40	1	...	·142	W.B.
			56·6	0·28	1	...	·947	L.
			58·3	0·29	1	...	·956	W.B.
β 552 ...	4 46	76 31	206·1	0·37	1	6·9 10·2	·156	L.
OΣ 98 ...	5 2	81 39	181·5	0·98	1	5·5 7·0	·025	B.
			175·1	0·66	1	...	·063	W.B.
			180·9	0·77	1	...	·947	L.
Σ 645 A.C.	5 3	62 5	25·6	12·05	1	6·0 8·5	·151	L.
β 1047 B.C.	...	...	61·3	0·46	1	8·5 8·8	·151	L.
Σ 687 A.B.	5 16	56 18	70·3	17·35	2	8·2 8·8	·176	L.
A.C.	...	...	153·5	48·78	2	8·2 8·8	·176	L.
β 886 C.D.	...	...	258·0	0·82	2	8·8 9·8	·176	L.
OΣ 105 ...	5 16	77 26	113·6	0·52	1	7·8 7·8	·151	L.
			109·5	0·47	1	...	·186	W.B.
β 887 A.B.	5 16	56 41	191·4	0·98	2	8·9 9·7	·176	L.
A.C.	...	...	113·9	9·87	2	8·9 13·0	·176	L.
A.D.	...	...	332·3	10·82	1	8·9 11·8	·176	L.
Dawes 5 (η Orionis)	5 19	92 29	78·1	1·33	1	3·5 5·5	·025	B.
β 889 A.B.	5 20	55 40	225·6	0·87	4	8·4 9·3	·130	L.
A.C.	...	...	104·1	3·97	1	... 14·1	·160	L.
A.D.	...	...	109·2	11·42	2	... 13·6	·160	L.

* Probably β 1044.

Star's Name.		R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1899.	Obs.
Σ 707	A.E.	...	...	132·8	18·24	3	...	10·0	·122	L.
*	...	5 21	55 20	302·5	2·30	1	8	11	·047	L.
Σ 719	A.B.	5 24	60 32	328·1	0·98	2	7·0	9·5	·176	L.
				328·4	1·04	1	...		·183	W.B.
	A.C.	...	...	350·9	15·01	3	7·0	8·9	·166	L.
Σ 749	...	5 31	63 8	173·7	0·85	1	7·1	7·2	·031	B.
				170·7	0·77	1	...		·063	W.B.
				173·8	0·82	1	...		·175	L.
β 1240	A.B.	5 32	59 34	351·0	0·20	3	5·6	6·0	·136	L.
Σ 753	A.C.	...	...	268·8	12·60	3	...	8·7	·136	L.
OΣ 112	...	5 33	52 6	73·8	0·62	2	7·5	7·5	·162	L.
				71·2	0·34	1	...		·189	W.B.
				73·3	0·63	1	...		·197	B.
β 91	...	5 41	69 6	90·6	1·43	1	8·1	10·0	·947	L.
OΣ 118	...	5 42	69 10	320·5	0·61	1	8·0	8·8	·036	B.
				312·8	0·58	2	...		·096	W.B.
				307·3	0·45	1	...		·947	L.
β 560	...	5 43	60 18	161·5	0·83	1	8·0	8·5	·036	C.
Σ 799	...	5 45	51 31	181·6	0·74	1	7·0	8·0	·085	W.B.
				179·2	0·85	1	...		·222	B.
				183·3	0·93	1	...		·233	L.
Σ 826	...	5 53	91 18	123·2	2·05	2	8·2	9·2	·110	L.
				159·8	0·45	1	...		·036	B.
β 1058 (4 Geminorum)		6 4	67 0	282·1	0·32	2	6·5	6·6	·192	W.B.
Σ 888	...	6 14	61 31	252·5	2·94	3	7·5	9·2	·088	L.
Σ 888	A.C.	6 14	61 31	252·5	2·94	3	7·5	9·2	·088	L.
β 895	A.B.	...	...	167·9	0·28	2	8·2	8·4	·155	L.
Σ 899	...	6 17	72 22	20·4	2·39	2	7·0	9·0	·123	B.
β 1020	...	6 17	61 11	157·8	1·01	3	8·2	10·0	·088	L.
Σ 919	A.B.	6 24	96 57	132·4	7·29	1	5·0	5·5	·953	B.
	B.C.	...	...	102·8	2·93	1	5·5	6·0	·953	B.
β 1021	...	6 25	61 33	86·9	0·68	2	8·1	9·4	·109	L.
Σ 932	...	6 28	75 10	322·9	2·18	2	8·2	8·3	·123	B.
Σ 936	...	6 30	31 48	266·4	1·52	2	7·0	8·7	·042	L.
OΣ 149	...	6 30	62 38	277·8	0·68	2	6·5	9·0	·107	W.B.
				278·7	0·68	2	...		·111	L.
Σ 945	...	6 33	48 56	267·0	0·75	1	7·1	8·0	·066	L.
				268·4	0·83	1	...		·090	B.

Star's Name.	R.A. 1900. h m	N.P.D 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights	Mags.	Epoch 1899.	Obs.
Σ 946 ...	6 36	30 24	129·8	4·06	1	7·2 9·0	·036	B.
Σ 948 ...	6 37	30 27	120·3	1·57	1	5·2 6·1	·036	B.
OΣ 156 ...	6 41	71 41	306·5	0·75	1	7·0 7·0	·066	L.
			297·1	0·59	3	...	·136	W.B.
OΣ 160 ...	6 48	68 42	172·1	1·18	3	7·0 10·0	·167	W.B.
β 899 A.B.	6 53	71 8	268·3	0·56	2	8·7 9·3	·185	L.
A.C.	...	...	175·3	24·66	1	8·7 10·0	·066	L.
A.D.	...	...	48·0	41·12	1	8·7 9·0	·066	L.
β 900 ...	7 0	68 49	275·6	1·50	3	8·0 11·5	·198	L.
OΣ 165 ...	7 2	73 54	40·4	3·71	2	5 11	·108	L.
β 1009 ...	7 5	59 36	183·6	2·10	1	4·5 13·2	·219	L.
Σ 1037 A.B.	7 6	62 35	305·0	0·92	1	7·0 7·1	·066	L.
			304·2	0·86	1	...	·090	B.
			299·0	0·84	3	...	·118	W.B.
β 1023 ...	7 9	63 56	301·5	0·21	2	8·4 8·5	·222	L.
OΣ 170 ...	7 11	80 31	111·3	1·54	1	7·0 7·5	·145	B.
			109·8	1·38	1	...	·162	W.B.
Σ 1074 ...	7 15	89 24	140·9	0·36	1	7·5 8·5	·060	B.
			138·1	0·55	1	...	·085	W.B.
β 1024 ...	7 17	60 30	164·5	2·38	1	9·0 11·3	·225	L.
OΣ 175 ...	7 28	58 50	333·4	0·73	2	6·0 6·6	·058	B.
			333·0	0·45	1	...	·084	W.B.
			334·5	0·61	3	...	·153	L.
Σ 1110 (Castor)	7 28	57 53	225·6	5·50	1	2·7 3·7	·025	B.
			224·3	5·64	2	...	·111	L.
β 579 ...	7 28	56 38	218·2	0·86	1	7·9 10·0	·219	L.
OΣ 176 ...	7 33	89 14	211·1	1·56	2	7·3 7·3	·162	B.
Σ 1126 ...	7 34	84 28	144·8	1·15	2	7·0 7·0	·171	B.
			142·3	1·29	1	...	·194	W.B.
OΣ 177 ...	7 35	52 19	121·7	0·81	1	7·5 8·5	·041	M.
			120·2	0·68	1	...	·101	B.
			124·2	0·61	2	...	·118	W.B.
OΣ 182 ...	7 47	86 20	216·1	1·13	2	7·0 7·5	·162	B.
β 101 (9 Argus)	7 47	103 38	295·9	0·32	1	5·2 6·5	·036	B.
Σ 1157 ...	7 49	92 30	244·3	1·21	2	8·0 8·0	·162	B.
Σ 1175 ...	7 57	85 32	223·5	1·75	1	8 9	·060	B.
			223·4	1·70	1	...	·194	W.B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
β 581 ...	7 59	77 26	272·9	0·37	1	8·5 8·6	·161	W.B.
OΣ 185 ...	7 52	88 35	195·1	0·37	1	6·8 7·1	·162	W.B.
			201·7	0·25	1	...	·192	B.
Σ 1187 ...	8 3	57 28	223·2	2·04	1	7·1 8·0	·041	W.B.
			224·9	2·17	1	...	·066	L.
			221·4	2·04	1	...	·090	B.
Σ 1196 A.B. (ζ Cancri)	8 6	72 3	8·2	1·09	3	5·0 5·7	·119	L.
			7·3	1·14	2	...	·147	W.B.
A.C.	...	...	114·0	5·68	3	5·0 5·5	·119	L.
			113·7	5·23	2	...	·147	W.B.
B.C.	...	...	127·2	5·78	3	5·7 5·5	·119	L.
			128·5	5·86	2	...	·147	W.B.
Σ 1202 ...	8 8	78 50	318·4	2·38	1	7·3 9·5	·129	W.B.
			320·0	2·51	1	...	·178	B.
β 1243 ...	8 8	72 1	301·7	0·92	1	7·2 12·2	·126	L.
β 1244 ...	8 8	87 41	40·7	0·63	1	7·9 8·1	·036	B.
Σ 1205 ...	8 11	33 14	175·9	0·98	1	8·8 9·3	·277	B.
Σ 1216 ...	8 16	91 14	193·9	0·47	2	7·5 8·2	·157	B.
Σ 1273 A.B. (ε Hydræ)	8 41	83 12	263·5	0·21	4	3·5 6·0	·230	L.
A.C.	...	...	233·1	3·81	1	3·5 7·4	·197	B.
			231·5	3·43	2	...	·210	L.
			235·7	3·38	1	...	·233	P.M.
A.D.	...	...	195·2	20·25	1	3·5 13·0	·233	L.
β 1068 ...	8 44	80 43	191·6	0·31	2	7·7 7·8	·178	W.B.
Perrotin ...	8 46	81 18	353·4	0·86	2	7·9 8·6	·135	W.B.
Σ 1316 A.B.	9 3	96 43	136·1	7·30	1	8·4 10·2	·277	B.
A.C.	...	...	170·7	7·32	1	8·4 10·0	·277	B.
B.C.	...	...	242·7	3·64	1	10·2 10·0	·277	B.
Σ 1321 ...	9 7	36 50	64·5	19·30	1	7·1 7·2	·277	B.
Σ 3121 ...	9 12	60 56	195·0	0·72	1	7·5 7·8	·126	L.
			194·9	0·60	1	...	·129	W.B.
			198·6	0·62	1	...	·197	B.
OΣ 201 ...	9 18	61 39	224·3	1·28	1	7·5 8·9	·126	L.
			219·5	1·25	1	...	·129	W.B.
			225·7	1·45	1	...	·197	B.
β 1070 ...	9 18	63 19	82·3	0·45	1	9·1 10·2	·126	L.
κ Leonis ...	9 19	63 2	202·7	2·83	1	...	·217	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
Σ 1348 ...	9 19	83 14	320·0	1·45	2	7·5 7·6	·169	W.B.
			323·4	1·86	1	...	·197	B.
Σ 1356 ...	9 23	80 27	111·6	0·64	4	6·2 7·0	·171	W.B.
β 1071 ...	9 27	37 54	87·1	5·00	1	3 14	·342	L.
Σ 1385 ...	9 44	72 55	352·5	0·78	1	8·4 11·1	·233	L.
OΣ 208 ...	9 45	35 28	283·3	0·23	3	5·0 5·6	·298	B.
			284·9	0·27	1	...	·405	L.
Σ 1389 ...	9 46	62 33	308·4	2·11	1	8·0 9·0	·183	W.B.
			313·4	2·08	1	...	·222	B.
			309·8	2·20	1	...	·290	L.
A.C. 5 ...	9 48	97 36	83·1	0·30	2	6 7	·279	B.
OΣ 215 ...	10 10	71 45	209·2	0·68	3	6·7 7·0	·171	W.B.
Σ 1424 ...	10 14	69 38	114·4	3·72	2	2·0 3·5	·192	W.B.
(γ Leonis)			113·7	3·68	2	...	·386	B.
Σ 1426 A.B.	10 15	83 2	280·8	0·69	2	7·8 8·3	·175	W.B.
A.C.	...	...	7·5	7·84	1	7·8 9·3	·189	W.B.
OΣ 216 ...	10 17	74 8	120·0	1·25	2	7 11	·259	B.
			123·6	1·27	1	...	·372	L.
Σ 1429 ...	10 19	64 50	250·1	0·95	3	8·1 8·5	·162	W.B.
			256·0	0·77	1	...	·290	L.
OΣ 217 ...	10 21	72 15	330·7	0·69	2	7·3 7·8	·152	W.B.
OΣ 218 ...	10 22	85 56	76·6	0·95	1	7 9	·142	W.B.
			77·2	0·94	2	...	·279	B.
OΣ 222 ...	10 32	29 17	344·8	4·24	1	6·7 10	·405	L.
Σ 1457 ...	10 33	83 44	314·6	0·94	1	7·4 8·2	·142	W.B.
			315·6	1·35	1	...	·197	B.
OΣ 224 ...	10 34	80 38	309·6	0·40	4	7·4 8·5	·341	B.
OΣ 225 A.B.	10 35	70 15	248·0	0·83	1	8·2 11·2	·189	W.B.
			250·3	0·65	4	...	·270	L.
A.C.	...	...	351·7	6·13	1	8·2 10·0	·189	W.B.
			352·1	6·44	3	...	·249	L.
OΣ 227 ...	10 37	78 44	346·1	0·40	1	8 9	·162	W.B.
			346·5	0·58	1	...	·222	B.
			341·6	0·48	1	...	·224	L.
Σ 1465 ...	10 37	44 50	8·6	1·88	1	8·7 9·2	·405	L.
			6·9	2·00	1	...	·413	W.B.
OΣ 228 ...	10 42	66 47	185·7	0·36	4	7 8	·164	W.B.
			189·2	0·48	1	...	·290	L.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1899.	Obs.
	h m	° ′	°	″					
OΣ 229 ...	10 44	48 21	320·1	0·82	2	6	7	·156	B.
			321·1	0·76	1	...		·389	L.
β 915 ...	10 44	65 11	227·8	0·95	1	9	9	·322	L.
			233·5	0·73	1	...		·375	B.
Σ 1476 ...	10 44	93 27	2·5	2·33	1	6·8	7·8	·277	B.
Σ 1487 ...	10 50	64 40	105·4	6·38	2	4·5	6·7	·250	B.
Σ 1500 ...	10 55	92 52	310·3	1·52	1	7·8	8·2	·277	B.
Σ 1501 ...	10 56	58 38	184·2	1·86	1	7·5	8·0	·222	B.
Σ 1504 ...	10 59	85 47	286·1	1·10	2	7·4	7·5	·241	W.B.
			287·4	1·13	1	...		·342	L.
β 599 ...	11 2	87 30	91·4	1·22	1	5·6	10·5	·342	L.
Σ 1510 ...	11 2	36 38	334·4	4·46	1	7·2	8·4	·222	B.
Σ 1517 ...	11 9	69 :8	98·2	0·29	2	7·0	7·5	·348	L.
Σ 1519 ...	11 10	29 40	290·6	1·26	1	8·2	9·2	·222	B.
Σ 1522 ...	11 11	87 52	180·1	2·61	1	8·9	11·1	·277	B.
			184·2	3·05	1	...		·342	L.
Σ 1523 (ξ Urs. Maj.)	11 13	57 53	155·7	2·15	2	4·0	4·9	·239	B.
			154·5	2·04	1	...		·353	L.
Σ 1534 ...	11 16	71 14	328·6	5·45	1	8·0	11·0	·474	B.
Σ 1536 ...	11 18	78 54	55·9	2·20	1	3·9	7·1	·255	B.
Σ 1527 ...	11 14	75 9	18·1	3·39	1	7·1	8·0	·222	B.
			19·7	3·60	1	...		·329	L.
Σ 1542 ...	11 23	44 54	259·4	3·21	1	7·0	10·2	·405	L.
			264·3	3·18	1	...		·435	W.B.
Lal. 21846...	11 24	58 59	4·7	0·82	2	7	11	·400	L.
OΣ 234 ...	11 26	48 11	134·2	0·34	3	7·0	7·4	·392	L.
OΣ 235 ...	11 26	28 20	112·4	0·59	2	6	7	·156	B.
Σ 1554 ...	11 31	76 36	251·5	0·69	...	8·9	9·1	·222	...
			258·6	0·72	...	...		·290	...
Σ 1555 A.B.	11 31	61 38	353·1	0·38	3	6·4	6·8	·286	L.
			351·4	0·48	1	...		·304	W.B.
A.C.	...	...	146·5	20·76	1	6·4	10·3	·290	L.
			144·7	21·02	1	...		·304	W.B.
Σ 1558 ...	11 33	67 56	152·5	1·39	1	8·7	9·2	·183	W.B.
			158·3	1·32	1	...		·222	B.
OΣ 237 ...	11 33	48 16	272·2	1·10	1	8	9	·381	L.
Σ 1566 ...	11 34	68 25	350·5	2·74	1	8·1	10·3	·222	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
β 603 ...	11 45	75 9	318·9	0·75	1	6·4 10·3	·222	B.
			322·2	0·78	2	...	·316	L.
Σ 1586 ...	11 52	49 6	251·7	1·64	2	8·2 10·2	·430	L.
			252·6	1·53	1	...	·435	W.B.
Σ 1601 ...	12 1	50 35	311·6	2·55	1	8·5 9·7	·183	W.B.
			305·8	2·32	1	...	·268	L.
			307·8	2·00	1	...	·408	B.
Σ 1606 ...	12 5	49 31	331·1	0·97	1	6·2 7·0	·405	L.
			329·2	1·00	1	...	·408	B.
Ho. 52 ... (11 Comæ)	12 15	71 39	44·1	8·80	2	5 13	·356	L.
Σ 1613 ...	12 18	53 40	14·5	1·00	1	8·2 8·4	·183	W.B.
			12·3	1·40	2	...	·362	L.
Σ 1639 ...	12 19	63 52	182·6	0·23	3	6·5 8·0	·328	L.
Σ 1643 ...	12 22	62 23	38·5	1·89	1	8·3 8·6	·238	W.B.
			39·6	2·03	2	...	·316	L.
Σ 1647 ...	12 25	79 44	218·6	1·34	1	7·5 8·0	·222	B.
			219·8	1·38	1	...	·290	L.
			223·0	1·22	1	...	·293	W.B.
Σ 1658 ...	12 30	81 58	358·1	2·24	1	8·0 9·8	·222	B.
			358·1	2·32	1	...	·290	L.
Σ 1663 ...	12 32	68 13	104·5	0·55	3	7·8 8·7	·293	W.B.
			102·3	0·59	2	...	·344	L.
Σ 1670 ... (γ Virginis)	12 36	90 52	147·7	5·58	1	3·0 3·0	·359	W.B.
			151·7	5·98	2	...	·386	B.
Σ 1687 A.B.	12 48	68 11	79·3	1·00	1	5·1 7·8	·293	W.B.
			80·2	1·09	3	...	·343	L.
			77·3	1·13	1	...	·397	B.
β 112 ...	12 55	71 4	294·6	2·12	1	9·1 9·8	·372	L.
			291·9	2·00	1	...	·397	B.
β 1082 ...	12 57	33 5	88·6	1·29	1	6·0 9·6	·038	B.
Σ 1711 ...	12 57	75 59	348·3	0·77	2	8·5 9·0	·332	W.B.
			351·8	1·03	1	...	·397	B.
β 929 ...	12 58	93 10	218·8	0·49	1	6·0 6·3	·397	B.
β 1083 A.B.	13 2	60 25	225·0	6·63	2	6·5 11·5	·325	L.
B.C.	...	...	225·0	0·58	1	11·5 11·7	·385	L.
* ...	13 2	62 31	192·3	0·43	1	9·0 9·5	·296	L.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1899.	Obs.
		h m	° ′	°	″					
OΣ 260	...	13 3	62 31	119·9	0·65	1	8	8	·293	W.B.
				125·6	0·64	4	...		·328	L.
Σ 1728	...	13 5	71 54	183·5	0·17	1	5·5	5·9	·293	W.B.
				187·0	0·25	4	...		·315	L.
OΣ 261	...	13 7	57 22	346·9	1·38	3	7·0	7·5	·394	L.
				346·4	1·37	1	...		·490	B.
β 800	...	13 12	72 26	117·6	2·56	3	7·5	10·2	·303	L.
				112·4	2·41	1	...		·490	B.
Σ 1734	...	13 15	86 30	189·8	0·98	2	7	8	·386	B.
Σ 1742	...	13 19	88 4	351·6	1·21	1	7·4	7·9	·375	B.
Ho. 260	...	13 19	60 15	318·4	0·74	2	8·1	8·2	·374	L.
OΣ 266	...	13 23	73 41	333·0	1·78	1	7·3	7·8	·274	L.
				340·4	1·57	1	...		·408	B.
Σ 1752	...	13 26	29 30	141·4	1·33	1	7·8	9·8	·451	B.
Σ 1755	...	13 28	52 40	131·3	4·31	1	6·8	7·9	·408	B.
OΣ 269	...	13 28	54 34	217·8	0·36	1	6·5	7·0	·359	W.B.
				221·2	0·36	2	...		·375	L.
				210·3	0·40	1	...		·408	B.
Σ 1757	...	13 29	89 45	78·5	2·24	1	8	9	·408	B.
Σ 1758	...	13 29	40 25	302·9	3·71	1	8·0	8·5	·408	B.
Σ 1768	...	13 33	53 10	127·8	1·19	1	5·0	7·6	·297	B.
				130·7	0·89	3	...		·402	L.
β 612	...	13 34	78 45	228·5	0·30	1	6·0	6·5	·394	L.
				215·1	0·41	1	...		·397	B.
Σ 1772	...	13 36	69 30	140·9	4·68	1	6·2	9·3	·408	B.
Σ 1777	...	13 38	85 55	231·2	3·09	1	5·8	8·2	·408	B.
Σ 1781	...	13 41	84 23	270·3	1·12	1	7·5	8·0	·408	B.
Σ 1785	...	13 45	62 30	271·3	1·34	1	7·2	7·5	·296	L.
				274·2	1·28	2	...		·364	W.B.
				274·5	1·17	1	...		·408	B.
β 613	...	13 47	54 50	144·0	0·71	1	9·1	9·1	·394	L.
				142·4	0·83	1	...		·397	B.
Σ 1788	...	13 49	97 33	79·6	2·75	1	7	8	·297	B.
β 30	...	13 53	70 2	199·9	8·37	1	8·0	11·0	·452	B.
β 1270	...	13 59	81 2	334·3	...	1	8·2	8·3	·427	L.
Σ 1802	...	14 2	102 22	280·3	4·98	1	7·7	8·7	·397	B.
Σ 1808	...	14 5	62 54	75·3	2·76	1	8·0	9·0	·296	L.
				73·2	2·74	2			·392	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1899.	Obs.
Σ 1810 ...	14 7	61 29	175·4	2·05	1	8·2	9·0	·293	W.B.
			176·7	1·93	2			·362	L.
OΣ 278 ...	14 8	45 21	95·4	0·27	3	7·5	7·5	·430	B.
Σ 1816 ...	14 9	60 26	84·6	1·25	1	7	7·1	·413	W.B.
			83·6	1·40	1			·427	L.
Σ 1817 ...	14 10	62 50	0·6	1·33	1	8·0	8·5	·293	W.B.
			3·4	1·12	2	...		·362	L.
Σ 1819 ...	14 10	86 22	2·5	1·21	1	7·9	8·0	·296	L.
			0·4	1·40	1	...		·452	B.
Σ 1832 ...	14 13	85 37	132·8	0·60	1	9	9	·296	L.
			132·5	0·40	1	...		·452	B.
β 1272 ...	14 14	40 47	131·2	1·24	2	8·4	9·5	·551	B.
β 1273 ...	14 15	41 35	192·8	1·02	2	8·6	9·8	·551	B.
Σ 1834 ...	14 17	22 58	200	elong.	1	7·5	7·5	·452	B.
Σ 1835 A B.	14 18	81 16	190·3	6·44	1	5·0	8·2	·296	L.
β 1111 B.C.	...	...	28·8	0·25	1	8·2	8·2	·296	L.
Σ 1837 ...	14 19	101 12	301·8	1·23	2	7·0	8·0	·425	B.
Σ 1820 ...	14 20	34 11	75·2	2·10	1	7·8	8·0	·452	B.
Σ 1846 ...	14 23	91 44	110·3	4·29	1	5·2	9·4	·375	B.
Σ 1863 ...	14 34	37 55	90·2	0·72	1	7	7½	·452	B.
Σ 1865 (ζ Boötis)	14 36	75 49	62·4	...	2	3·5	3·9	·414	B.
Σ 1867 ...	14 36	58 15	11·3	1·03	1	7·7	8·2	·342	L.
			14·9	1·28	1	...		·649	B.
Σ 1877 (ε Boötis)	14 38	62 29	332·6	2·73	2	3·0	6·3	·362	L.
			326·3	2·86	1	...		·452	B.
Σ 1871 ...	14 38	38 6	291·4	1·88	2	7	7	·636	B.
Σ 1876 ...	14 41	90 46	79·7	1·27	1	8·0	8·4	·452	B.
Σ 1879 ...	14 41	79 55	130·7	0·45	1	8·0	8·5	·293	W.B.
			142·7	0·48	2	...		·373	L.
OΣ 285 ...	14 42	47 11	135·2	0·34	3	7·1	7·6	·327	L.
Σ 1883 ...	14 44	83 38	242·3	0·44	2	7·0	7·0	·425	B.
Σ 1884 ...	14 44	65 12	54·3	1·48	1	6·3	7·4	·375	B.
			54·2	1·53	1	...		·427	L.
Σ 1885 ...	14 46	89 34	144·1	3·73	1	8·4	8·9	·397	B.
Σ 1888 ...	14 47	70 27	209·5	2·52	1	5·1	7·4	·375	B.
			207·3	2·89	1	...		·427	L.
OΣ 287 ...	14 57	44 38	319·9	0·73	2	8	9	·345	L.
			324·9	0·77	1	...		·452	B.

Star's Name.		R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1899.	Obs.
β 31	A.B.	14 48	70 50	196·2	1·39	2	8·4	9·7	·436	L.
				201·8	1·10	1	...		·452	B.
	A.C.	...	...	...	...	...	8·4	12·2	...	...
Σ 1891	...	14 51	55 28	239·2	3·74	1	8·4	10·0	·397	B.
Σ 1908	...	15 1	55 7	142·3	1·41	1	8	9	·356	L.
				138·9	1·19	1	...		·375	B.
Hough 60	...	15 10	54 44	41·7	0·28	1	8	8	·334	L.
				31·7	0·19	1	...		·375	B.
Σ 1926	...	15 12	51 20	252·0	0·84	1	7·7	9·2	·353	L.
Σ 1932	...	15 14	62 45	149·1	0·62	1	5·5	6	·375	B.
				148·6	0·71	4	...		·418	L.
				145·6	1·05	2	...		·424	W.B.
Hough 62	...	15 17	54 40	283·9	1·18	2	8·2	8·3	·512	B.
Σ 1937	...	15 19	59 19	172·0	0·57	2	5	5·5	·345	L.
				171·4	0·66	1	...		·356	D.
				175·6	0·31	1	...		·375	B.
Σ 1938	...	15 20	52 16	75·7	0·83	2	4	6	·345	L.
				74·0	1·17	1	...		·356	D.
				78·4	1·10	1	...		·375	B.
Σ 1954	...	15 30	29 7	187·8	3·72	1	3·9	5·5	·375	B.
				187·0	3·53	1	...		·444	L.
Σ 1957	...	15 31	76 44	156·0	0·97	1	8·0	9·5	·449	L.
				152·8	0·99	2	...		·463	W.B.
OΣ 298	...	15 32	49 50	176·2	1·16	1	7	8	·334	L.
				183·1	0·85	1	...		·649	B.
Σ 1967 (γ Cor.Bor.)	...	15 38	63 18	118·2	0·34	2	4·0	7·0	·414	B.
				117·0	0·43	3	...		·416	L.
Σ 1974	...	15 44	92 51	104·1	2·34	1	8·5	8·7	·452	B.
OΣ 303	...	15 56	76 28	145·8	0·68	1	7·0	8·0	·375	B.
				144·9	0·71	1	...		·449	L.
				139·6	0·77	3	...		·453	W.B.
Σ 2004	...	16 0	60 52	282·4	1·74	1	8·7	9·7	·375	B.
				277·6	1·58	2	...		·392	L.
Σ 2011	...	16 4	60 44	67·8	2·44	1	7·2	9·8	·375	B.
				66·8	2·14	2	...		·392	L.
Σ 2015	A.C.	16 5	44 21	157·7	2·81	1	7·8	8·8	·616	B.
				158·6	2·83	1	...		·695	W.B.
β 355	A.B.	16 5	44 21	277·7	0·28	1	7·8	8·9	·695	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
Σ 2022 A.D.	16 9	63 4	136·6	2·55	1	6·2 9·8	·427	L.
			131·1	2·12	1	...	·446	W.B.
Σ 2032 ...	16 11	55 53	212·6	4·34	3	5·0 6·1	·532	B.
Σ 2026 ...	16 12	82 21	269·3	0·69	1	8·5 9·5	·542	L.
Σ 2037 ...	16 15	37 14	236·6	1·35	1	9 9	·446	W.B.
β 951 ...	16 20	56 26	51·7	0·87	3	8·1 9·0	·409	L.
Σ 2052 ...	16 24	71 21	92·0	1·80	1	7·5 7·5	·542	L.
			93·6	1·81	1	...	·605	B.
β 814 ...	16 24	49 53	323·1	0·33	1	8·4 8·4	·411	L.
Σ 2054 ...	16 24	28 4	1·0	0·95	1	5·7 6·9	·512	W.B.
			357·5	1·22	1	...	·530	B.
OΣ 312 ...	16 24	28 16	141·4	4·95	1	2·1 8·1	·512	W.B.
			139·7	5·16	1	...	·536	B.
Σ 2055 (λ Ophiuchi)	16 25	87 47	54·8	1·07	1	4·0 6·1	·444	L.
			54·4	1·24	1	...	·682	B.
Σ 3105 ...	16 26	96 48	28·3	0·45	1	7·5 7·5	·444	L.
			266·3	0·57	3	...	·328	L.
Σ 2084 (ζ Herculis)	16 37	58 12	266·1	0·59	3	3·0 6·5	·391	L.
			261·5	0·60	1	...	·468	W.B.
			261·7	0·63	2	...	·486	L.
			259·3	0·65	2	...	·597	L.
			260·7	0·55	1	...	·622	W.B.
Σ 2091 ...	16 39	48 37	303·5	0·99	1	7·5 8·0	·613	W.B.
			304·8	1·07	1	...	·663	B.
			303·1	0·89	1	...	·704	L.
De 15 ...	16 40	46 20	323·3	0·52	1	8·0 8·5	·411	L.
			325·0	0·37	1	...	·695	L.
Σ 2094 A.B.	16 40	66 19	74·7	1·23	1	7·3 7·6	·446	B.
A.C.	...	...	312·2	24·83	1	7·3 11·0	·446	B.
Σ 2106 ...	16 46	80 25	306·0	0·36	1	6·7 8·4	·449	L.
Σ 2107 ...	16 48	61 10	307·6	0·31	1	6·7 8·5	·449	L.
Σ 3107 ...	16 53	85 55	98·5	1·41	1	8·5 8·5	·449	L.
Σ 2112 ...	16 55	58 4	263·3	1·87	1	8·5 9·5	·543	L.
Σ 2114 ...	16 57	81 24	160·1	1·06	1	6·5 8·0	·447	L.
			155·6	1·04	2	...	·504	W.B.
Σ 2118 ...	16 57	24 50	27·4	0·18	1	5·5 6·5	·528	B.
β 357 ...	17 1	79 19	113·5	1·18	1	8·4 9·4	·449	L.
			113·9	1·18	1	...	·561	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1899-	Obs.
β 823 ...	17 1	89 13	8·8	1·09	1	8·7	9·5	·449	L.
Σ 2130 ...	17 3	35 24	326·6	2·21	1	5	5	·528	B.
Σ 2140 (α Herculis)	17 10	75 30	115·9	4·78	4	3·0	6·1	·569	L.
			112·9	4·75	1	...		·605	B.
OΣ 327 ...	17 12	33 45	305·0	0·17	1	7·6	8·0	·528	B.
β 628 ...	17 15	57 14	358·5	0·42	1	8·7	9·3	·411	L.
			2·0	0·47	1	...		·650	B.
β 629 ...	17 15	57 50	340·6	1·08	2	8·4	8·7	·480	L.
β 45 ...	17 15	...	286·8	4·54	1	...		·624	W.B.
			292·1	5·12	1	...		·663	B.
Swift ...	17 15	36 11	320·8	0·43	1	8·9	9·0	·528	B.
β 630 ...	17 17	57 36	220·9	1·40	1	8·5	9·6	·549	L.
β 1250 ...	17 21	59 9	65·5	1·82	2	9·4	9·5	·545	L.
Σ 2173 ...	17 25	90 56	328·1	1·07	1	5·8	6·3	·534	W.B.
			331·5	0·96	1	...		·570	L.
			334·4	1·17	1	...		·680	B.
OΣ 331 ...	17 26	87 1	333·9	0·91	2	8	9	·551	W.B.
			336·5	0·75	1	...		·570	L.
β 1201 ...	17 27	...	343·3	0·31	1	...		·512	B.
β 1121 ...	17 33	77 24	232·8	0·54	2	8·5	9·0	·589	L.
β 631 ...	17 35	90 35	60·8	0·47	1	7·5	7·6	·681	B.
Σ 2192 ...	17 36	60 43	62·2	5·06	1	7·3	10·2	·457	W.B.
Σ 2199 ...	17 37	34 12	84·5	1·66	2	7	8	·548	B.
Σ 2207 ...	17 38	22 56	129·5	0·74	1	8·0	8·5	·506	B.
Σ 2203 ...	17 38	48 18	314·8	0·75	1	7·5	7·8	·772	B.
β 1251 ...	17 38	73 59	60·3	1·21	2	6·0	11·5	·589	L.
Σ 2206 ...	17 40	70 59	246·8	0·95	1	8·1	9·7	·446	W.B.
Σ 2218 ...	17 40	26 22	343·2	1·71	1	7·8	7·8	·512	W.B.
			349·8	1·91	1	...		·523	B.
Σ 2205 ...	17 41	72 15	304·2	2·06	1	8·3	8·6	·457	W.B.
			306·1	2·20	1	...		·528	L.
Σ 2215 ...	17 42	72 16	288·4	0·58	2	6	8	·568	L.
			285·6	0·74	2	...		·576	W.B.
Hough 70 ...	17 42	59 25	111·6	0·37	1	8	8	·772	B.
Σ 2222 ...	17 43	75 8	58·0	2·18	1	7	8·5	·457	B.
Σ 2228 ...	17 45	...	343·2	1·71	1	...		·506	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
OΣ 338 ...	17 47	74 39	20·6	0·65	1	6·5 7·0	·570	L.
			15·5	0·56	1	...	·695	W.B.
			18·2	0·50	1	...	·772	B.
A.C. 9 ...	17 50	60 10	235·1	1·11	1	8·4 8·7	·772	B.
Ho. 72 A.B.	17 52	56 33	1·3	7·23	1	9 11	·723	L.
A.C.	...	...	33·2	9·35	1	9 13	·723	L.
Σ 2258 ...	17 54	41 22	223·0	2·24	1	8·5 8·7	·865	L.
β 1125 ...	17 57	88 40	18·2	0·77	1	5·0 8·5	·608	L.
Σ 2262 (T Ophiuchi)	17 58	98 11	258·9	1·93	3	5 6	·617	B.
Σ 2267 ...	17 58	49 49	65·1	0·97	1	8·5 8·7	·372	L.
			63·1	1·15	1	...	·737	B.
β 1127 ...	17 59	45 47	141·7	0·76	1	7·8 9·7	·865	L.
* ...	18 0	45 47	134·3	0·53	1	8·9 9·0	·372	L.
			130·8	0·34	2	...	·677	B.
A.C. 15 ... (99 Herculis)	18 3	59 27	309·5	0·98	1	6·0 11·0	·608	L.
Σ 2281 ...	18 4	86 2	239·5	0·41	2	5·7 7·2	·684	B.
Σ 2283 ...	18 4	83 52	81·0	0·92	3	7·2 7·7	·479	W.B.
			82·5	0·81	1	...	·648	B.
Σ 2289 ...	18 5	73 32	231·8	0·99	4	6·5 7·0	·523	W.B.
			230·9	1·22	1	...	·630	B.
Σ 2294 ...	18 9	89 51	107·7	0·37	1	7·4 7·7	·630	B.
OΣ 341 ...	18 2	68 34	280·9	0·17	1	7·0 7·5	·772	B.
Σ 2292 ...	18 7	62 23	262·7	1·21	1	8·0 8·1	·446	W.B.
			265·7	1·18	1	...	·548	L.
β 1091 ...	18 9	51 26	38·6	0·28	1	8·6 8·6	·772	B.
β 1274 B.C.	18 13	33 27	103·4	0·72	1	9·8 10·6	·405	L.
B.D.	...	...	7·6	4·38	1	9·8 10·4	...	
β 641 ...	18 17	68 33	344·2	0·90	3	7·3 9·0	·519	W.B.
			351·0	0·90	1	...	·570	L.
			191·5	2·44	1	...	·457	W.B.
β 1203 ...	18 21	89 15	59·0	0·31	1	7·5 7·7	·630	B.
Σ 2315 ...	18 21	62 39	198·3	0·30	2	7·5 9·0	·586	L.
OΣ 543 ...	18 23	43 11	124·8	1·14	1	8·0 10·0	·616	B.
			134·3	1·02	1	...	·695	W.B.
OΣ 351 ...	18 23	41 19	21·8	0·65	1	7·0 7·0	·411	L.
			22·2	0·58	1	...	·616	B.
Σ 2323 ...	18 23	31 16	0·8	3·20	1	4·7 7·7	·528	B.

Star's Name.		R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
		h m	° ′	°	″				
OΣ 354	...	18 26	83 18	171·9	0·95	1	7 8	·611	W.B.
				170·1	0·90	3	...	·623	B.
OΣ 357	...	18 31	78 24	246·8	0·49	3	8·2 8·2	·600	W.B.
				244·5	0·32	3	...	·645	B.
OΣ 358	...	18 31	73 12	192·4	1·89	1	7·0 7·5	·611	W.B.
				192·4	1·77	3	...	·617	B.
Σ 2356	...	18 34	61 23	57·4	1·12	2	8·2 8·6	·628	W.B.
*	...	18 34	61 18	253·9	1·18	2	9·0 10·0	·628	W.B.
Hough 87	...	18 34	73 34	102·5	0·30	2	7·8 8·1	·681	W.B.
				102·2	0·36	1	...	·772	B.
Σ 2367	A.B.	18 37	59 48	258·8	0·22	3	7·2 7·6	·540	L.
				255·9	0·30	1	...	·622	W.B.
	A.C.	...	...	193·0	14·23	1	7·2 8·2	·608	L.
Hough	437	18 37	58 27	104·0	0·34	1	8 8	·772	B.
Σ 2384	...	18 39	22 58	304·8	0·40	1	8·0 8·2	·506	B.
				312·6	0·59	1	...	·512	W.B.
Σ 2369	...	18 39	87 30	89·7	0·91	1	8 8	·693	B.
Σ 2400	A.B.	18 44	73 51	185·9	0·29	2	8·0 11·1	·526	L.
	A.C.	...	...	185·8	3·24	2	8·0 11·0	·526	L.
Σ 2402	...	18 45	79 25	206·1	0·82	4	8·0 8·4	·500	W.B.
				203·3	1·05	1	...	·648	B.
Σ 2409	...	18 47	76 35	29·4	1·11	1	8·0 9·3	·611	W.B.
Σ 2410	...	18 47	30 49	93·8	1·48	1	8·2 8·7	·528	B.
Σ 2412	...	18 48	76 8	54·1	1·30	1	8·4 8·5	·611	W.B.
β 137	...	18 50	52 45	131·4	1·27	1	8·2 11·5	·444	L.
*	...	18 50	55 30	84·6	5·13	1	8·0 10·0	·444	L.
Σ 2415	...	18 51	69 32	288·4	1·69	1	6·6 8·5	·611	L.
β 648	...	18 53	57 16	222·4	0·96	1	6·0 9·2	·444	L.
Σ 2422	...	18 53	63 54	95·2	0·66	2	7·9 8·2	·504	L.
				90·8	0·80	2	...	·548	W.B.
β 649	...	18 55	57 40	9·0	1·91	1	8·2 10·6	·444	L.
Σ 2438	...	18 56	31 56	211·3	0·32	2	7·2 7·7	·430	L.
				212·1	0·27	1	...	·528	B.
Σ 2437	...	18 57	70 59	60·8	0·70	2	7·8 8·2	·548	W.B.
Σ 2451	...	19 1	38 36	69·8	2·05	1	8·7 9·0	·537	L.
Σ 2454	...	19 2	59 43	248·9	0·95	1	8 9	·605	B.
				241·6	0·91	2	...	·616	W.B.
Σ 2478	...	19 3	20 43	303·2	1·16	2	8·8 8·8	·518	W.B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
Σ 2455 ...	19 3	67 59	79·8	3·22	2	7 8	·611	B.
Hough 98 ...	19 4	62 2	322·9	0·36	2	8 8	·572	L.
			323·7	0·35	2	...	·575	W.B.
			320·5	0·32	1	...	·605	B.
* ...	19 5	63 13	78·7	0·84	1	8·5 10	·572	L.
			79·7	1·11	1	...	·575	W.B.
			72·8	1·14	1	...	·605	B.
Σ 2464 ...	19 5	78 15	23·9	1·09	1	8·2 10·5	·578	W.B.
β 1204 ...	19 7	87 33	12·1	0·37	3	7·7 8·5	·716	B.
OΣ 368 A.B.	19 11	74 1	213·7	0·82	3	8 9	·585	W.B.
			210·3	0·80	2	...	·600	L.
A.C.	...	...	101·7	17·72	1	...	·611	W.B.
OΣ 371 ...	19 12	62 42	150·5	0·77	1	7 7	·534	W.B.
			156·6	0·75	1	...	·580	L.
Σ 2490 ...	19 13	93 37	243·3	3·03	1	8·5 10·7	·791	B.
Σ 2491 ...	19 13	61 52	218·7	0·95	1	7·9 9·2	·611	W.B.
			216·4	0·85	1	...	·717	L.
H.A.H. 95...	19 15	87 14	150·9	0·27	1	6·0 6·5	·630	B.
			149·0	0·50	2	...	·681	W.B.
			147·7	0·48	1	...	·745	L.
β 141 ...	19 18	67 42	81·5	0·89	1	7·5 8·5	·567	W.B.
β 1129 ...	19 19	37 50	343·0	0·28	1	6·3 6·3	·772	B.
Σ 2525 ...	19 22	62 52	317·2	0·42	3	8·0 8·0	·617	W.B.
			319·9	0·46	4	...	·680	L.
			314·4	0·39	1	...	·772	B.
Σ 2536 ...	19 26	72 25	74·8	1·77	1	8 11	·605	B.
* ...	19 27	72 10	344·0	11·32	1	10·5 11	·605	B.
β 438 A.B.	19 28	53 32	37·0	4·59	1	8·0 12·7	·746	L.
C.D.			53·9	5·92	1	7·9 8·3	·746	L.
A.E.			235·3	21·74	1	8·0 12·8	·746	L.
Σ 2539 ...	19 28	61 57	361·2	5·44	1	7·9 9·7	·533	B.
β Cygni ...	19 28	62 15	55·2	34·19	2	3 7	·675	L.
OΣ 375 ...	19 30	72 7	144·6	0·39	3	8·0 9·0	·569	W.B.
Σ 2544 ...	19 32	81 56	208·4	0·77	1	8 10	·643	W.B.
			206·8	1·03	1	...	·739	L.
			209·3	1·12	1	...	·791	B.
Σ 2553 ...	19 33	28 10	115·2	0·83	1	8 9	·523	W.B.
			97·4	0·94	1	...	·529	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° '	°	"				
Σ 2556 ...	19 35	68 0	145·2	0·43	4	7 8	·560	W.B.
β 1132 ...	19 39	63 18	225·4	0·40	2	8·3 8·7	·589	W.B.
			221·5	0·43	5	...	·662	L.
*	19 39	63 18	346·0	3·27	1	9·0 9·5	·580	L.
			344·3	3·54	1	...	·611	W.B.
β 658 ...	19 40	62 9	286·6	0·47	3	6·7 9·7	·696	L.
			290·0	0·60	2	...	·725	W.B.
Σ 2574 ...	19 40	27 35	336·6	0·43	1	8·0 9·0	·528	B.
Σ 2579 (δ Cygni)	19 42	45 7	125·0	1·32	1	3 8	·772	B.
Σ 2592 ...	19 42	13 40	295·9	1·22	1	8·0 9·9	·528	B.
Σ 2585 A.C. (ζ Sagittæ)	19 44	71 7	309·0	8·57	2	4·5 8·0	·679	L.
			308·6	8·42	1	...	·687	W.B.
A.G.C. 11 A.B.	...	...	159·2	0·22	2	4·5 6·0	·679	L.
			166·1	0·25	1	...	·687	W.B.
Hough 506	19 45	...	271·9	0·72	2	8 8·1	·573	W.B.
Σ 2597 ...	19 50	97 0	84·6	1·42	3	6·9 8·0	·726	B.
Σ 2600 ...	19 51	67 46	57·9	2·76	2	8·3 9·7	·633	W.B.
β Aquilæ ...	19 51	83 52	12·5	12·45	1	3 12	·791	B.
η Cygni ...	19 53	55 12	214·5	7·54	1	4·0 13·0	·739	L.
β 425 ...	19 53	69 59	241·7	1·36	2	8·4 8·5	·611	B.
			238·5	1·30	1	...	·619	L.
			243·9	1·28	1	...	·622	W.B.
A.C. 16 ...	19 54	63 2	55·5	0·50	2	7 9	·616	W.B.
			57·8	0·40	1	...	·616	B.
			55·2	0·32	1	...	·619	L.
Σ 2607 A.D.	19 54	48 0	296·5	0·30	1	7 9	·739	L.
A.C.	...	...	289·6	2·91	1	7 9	·739	L.
β 1133 ...	19 56	58 27	340·7	0·76	2	6·8 9·5	·745	L.
			338·5	1·00	1	...	·775	W.B.
β 1258 ...	19 56	60 23	161·3	1·42	2	8·0 10·7	·668	L.
			156·8	1·03	1	...	·797	W.B.
*	19 55	60 23	129·7	3·70	1	9 9·5	·717	L.
Σ 2616 ...	19 58	75 42	266·0	3·73	1	6·8 9·7	·797	W.B.
Σ 2620 ...	20 0	78 30	285·2	1·60	3	8·2 9·3	·655	W.B.
Σ 2624 A.B.	20 0	54 16	174·9	1·89	1	7·2 7·8	·797	W.B.
A.C.	...	...	172·1	29·02	1	7·2 9·5	·297	W.B.
A.D.	...	...	328·2	42·50	1	7·2 10·0	·297	W.B.
Σ 2642 ...	20 5	26 36	352·7	2·16	1	8·7 8·7	·528	B.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1899.	Obs.
	h m	° ′	°	″				
Σ 2652 ...	20 8	28 12	76·2	0·26	1	7·5 7·7	·528	B.
Σ 2695 ...	20 28	64 39	75·5	0·99	2	6·2 8·0	·581	L.
			74·0	0·99	2	...	·661	W.B.
β 151 A.B.	20 33	75 46	6·8	0·43	2	4·5 6·0	·623	B.
(β Delphini)			6·4	0·41	4	...	·683	W.B.
			5·6	0·56	3	...	·721	L.
β 151 A.C.	...	...	116·2	25·60	1	4·5 11·0	·630	B.
A.D.	...	...	331·7	37·25	1	4 11	·630	B.
β 64	20 40	77 40	189·4	0·48	1	8·3 8·3	·630	B.
			182·9	0·46	5	...	·646	W.B.
Σ 2729	20 46	96 4	198·2	0·24	1	6 7	·630	B.
β 367	20 51	62 18	128·2	0·46	2	8·0 8·6	·681	W B.
			133·2	0·45	4	...	·732	L.
Barnard ...	20 52	86 27	86·2	1·44	1	10·1 11·3	·791	B.
OΣ 424 ...	20 54	74 50	321·1	0·44	3	8·0 9·3	·630	B.
			328·7	0·39	1	...	·671	L.
β 69 ...	20 58	68 43	308·2	1·01	2	8·3 9·1	·675	W.B.
Σ 2737 A.B.	20 54	86 7	286·2	0·62	1	5·7 6·2	·761	L.
(ε Equulei)			284·1	0·55	1	...	·764	W.B.
			279·3	0·77	1	...	·791	B.
A.C.	...	...	72·8	10·46	1	5·7 7·1	·764	W.B.
			72·9	10·59	1	...	·291	B.
β 156 ...	20 58	43 50	241·3	1·03	1	7·5 9·9	·780	B.
			247·8	1·01	1	...	·792	W.B.
			247·6	0·96	1	...	·865	L.
Σ 2744 ...	20 58	88 51	159·2	1·35	1	6·5 7·5	·764	W.B.
			166·2	1·36	2	...	·782	B.
			167·0	1·42	1	...	·827	L.
Σ 2749 A.B.	21 0	86 52	156·7	2·71	2	7·7 8·9	·694	B.
			152·9	2·92	1	...	·827	L.
A.D.	...	...	152·9	0·58	1	7·7 8·9	·827	L.
B.C.	...	...	156·9	1·18	2	8·9 10·0	·694	B.
			149·9	1·10	1	...	·827	L.
OΣ 527 ...	21 4	85 17	97·4	0·38	2	7 8·5	·696	B.
			110·9	0·66	1	...	·764	W.B.
Hough 152	21 8	62 7	324·7	0·60	3	8·5 9·5	·668	W.B.
τ Cygni ...	21 10	52 24	307·2	0·60	1	3·9 10·0	·865	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900 ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
OΣ 535 ...	21 10	80 27	201·7	0·17	1	4·1 4·1	·630	B.
			190·3	0·23	1	...	·761	L.
			191·9	0·28	1	...	·770	W.B.
β 163 ...	21 13	78 52	249·7	0·69	1	7 10	·630	B.
			255·5	0·69	2	...	·841	W.B.
β 838 ...	21 15	87 20	95·7	1·38	2	8 9	·711	B.
β 1212 ...	21 34	90 33	267·8	0·49	2	6·5 6·9	·696	B.
			261·6	0·51	1	...	·775	W.B.
Hough 165 A.B.	21 38	71 29	72·0	0·41	2	8 8·2	·725	W.B.
	...	...	68·5	0·47	3	...	·808	L.
A.C.	...	...	21·7	20·29	2	...	·837	L.
Σ 2822 ...	21 39	61 43	125·4	2·65	2	4 5	·734	L.
Σ 2824 A.C. (κ Pegasi)	21 40	64 51	298·1	12·44	3	3·9 10·8	·788	L.
β 989 A.B.	...	...	278·3	0·17	2	3·9 5·0	·575	L.
			281·4	0·21	2	...	·720	L.
			271·4	0·19	3	...	·767	L.
			274·6	0·15	1	...	·797	W.B.
			269·2	0·20	2	...	·836	L.
Hough 166	21 40	62 38	99·8	0·42	1	7·5 7·5	·687	W.B.
			97·8	0·41	2	...	·734	L.
Σ 2825 ...	21 42	89 38	117·8	0·83	1	8 9	·846	L.
Hough 171	21 48	62 41	173·7	0·61	2	8 8	·720	L.
β 75 ...	21 50	79 35	42·3	0·96	3	8·1 8·3	·754	W.B.
			38·2	1·16	2	...	·786	B.
			40·1	0·90	1	...	·832	L.
Σ 2849 ...	21 53	76 19	261·1	1·51	2	8·2 10·7	·656	W.B.
Hough 176	21 57	66 56	183·9	0·93	2	8 11	·671	W.B.
Hough 179	22 8	60 28	258·5	0·47	3	8·0 8·5	·727	W.B.
			254·9	0·45	1	...	·780	B.
Σ 2878 ...	22 9	82 33	125·7	1·02	1	6·5 8·0	·791	B.
Σ 2881 ...	22 10	60 57	96·5	1·58	2	7·7 8·2	·671	W.B.
			98·1	1·56	2	...	·737	L.
Hough 180	22 12	46 38	224·2	0·60	1	7·0 7·5	·865	L.
β 1216 ...	22 15	61 0	307·3	0·53	2	8·4 8·7	·704	W.B.
			308·7	0·49	2	...	·736	L.
			308·5	0·55	1	...	·780	B.
β 172 ...	22 19	95 23	10·6	0·68	2	5·6 6·0	·755	B.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
Σ 2900 ...	22 19	69 40	171·4	1·23	3	6·0 9·2	·760	W.B.
β 291 A.B.	22 23	86 0	175·0	0·31	1	8·4 8·7	·630	B.
			168·5	0·34	1	...	·761	L.
A.C.	...	...	125·0	31·90	1	8·4 10·0	·761	L.
β 1218 ...	22 23	60 50	53·3	1·42	1	8·6 8·8	·654	W.B.
			54·6	1·49	2	...	·737	L.
			51·1	1·54	1	...	·780	B.
Σ 2912 (37 Pegasi)	22 25	86 6	110·2	0·34	1	6·5 7·8	·737	B.
			108·0	0·30	1	...	·761	L.
Hough 296	22 36	75 59	75·7	0·43	1	5·5 5·5	·775	W.B.
			277·7	0·42	1	...	·846	L.
Σ 2934 ...	22 37	69 6	144·4	0·88	4	8·2 9·2	·671	W.B.
β 710 ...	22 38	60 50	232·3	0·42	2	8·0 8·5	·737	L.
			234·3	0·42	1	...	·764	W.B.
			235·0	0·42	1	...	·780	B.
β 144 ...	22 38	60 18	85·9	0·31	1	10 10	·723	L.
			81·1	0·36	1	...	·906	W.B.
β 711 ...	22 40	79 20	44·5	1·07	1	9 10	·780	B.
			52·0	0·75	1	...	·870	W.B.
			55·1	0·58	1	...	·846	L.
Σ 2944 ...	22 42	94 47	256·3	3·11	1	7·0 7·5	·780	B.
β 1037 ...	22 43	77 32	232·3	0·69	1	8·5 10·5	·846	L.
β 1146 ...	22 44	59 26	329·6	0·27	1	7·2 8·2	·780	B.
			316·2	0·20	1	...	·817	L.
β 382 ...	22 49	45 47	226·8	0·79	1	7·3 8·8	·780	B.
			232·0	0·75	1	...	·893	L.
OΣ 536 A.B.	22 53	81 10	230·0	0·24	1	7·3 7·4	·846	L.
A.C.	...	...	241·0	15·64	1	7·3 10·0	·846	L.
OΣ 483 ...	22 54	78 48	222·0	0·53	3	6·0 7·5	·745	W.B.
β 1025 ...	23 9	77 53	266·2	0·84	1	8·0 10·8	·654	W.B.
β 79 ...	23 12	92 5	83·3	0·84	1	8 8·5	·772	B.
			88·0	0·44	1	...	·775	W.B.
Σ 2995 ...	23 12	92 8	33·2	5·01	1	7·7 8·0	·025	B.
β 80 ...	23 14	85 10	343·8	0·45	1	8 8·5	·025	B.
			350·3	0·42	2	...	·755	B.
β 1222 ...	23 23	87 0	40·0	1·33	2	9 9	·755	B.
β 1266 ...	23 25	59 43	228·7	0·22	1	7·2 7·5	·861	L.

Star's Name.	R.A. 1900. h m	N.P.D. 1900. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1899.	Obs.
β 720 ...	23 29	59 14	157·4	0·33	3	5·5 5·5	·779	W.B.
			163·9	0·31	1	...	·780	B.
			162·1	0·38	3	...	·813	L.
β 858 ...	23 36	58 0	267·7	0·58	1	8·0 8·2	·780	B.
			260·1	0·52	2	...	·831	L.
A.G.C. 14 ...	23 39	61 12	194·3	1·23	1	5·5 9·7	·780	B.
			196·9	1·28	1	...	·830	W.B.
			196·9	1·25	2	...	·834	L.
Σ 3037 ...	23 41	30 5	213·7	2·67	1	7·0 8·5	·068	B.
Barnard ...	23 42	85 18	166·8	0·62	1	8·6 8·6	·737	B.
Σ 3047 ...	23 54	33 10	72·5	1·26	1	8·7 8·7	·068	B.
Σ 3050 ...	23 54	56 51	214·3	2·37	1	6·0 6·0	·797	W.B.
			214·3	2·40	1	...	·832	L.
Σ 3056 ...	23 59	56 20	153·7	0·40	1	7 8	·893	L.

Measures of Double Stars from Photographs taken at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The photographs were taken with the 26-inch refractor of the Thompson Equatorial, the stars photographed being either bright stars with faint companions, or selected double stars which seemed well suited for photographic measurement. For the former an occulting shutter, carried by an arm pivoted in the side of the dark slide, was used to screen the bright star, a series of short intermittent exposures for it being given during the long exposure required for the companion by raising the arm of the shutter by hand and allowing it to fall back into position again as rapidly as practicable. In order to allow of still shorter exposures in the case of very bright objects a useful modification was introduced by Mr. Davidson. In the new arrangement the shutter consists of two parts separated by a narrow slit, so that the exposure is given only during the rapid passage of the slit across the star's image, and by this device it is found practicable to give exposures of about $0^{s}\cdot01$ only in duration.

The exposures given to the photographs were, as far as possible, such as would give small and sharp images; for bright pairs dry collodion plates were sometimes used, but for stars with faint companions Ilford special rapid plates were used. A second exposure was given for orientation, the clock being put out of

gear for about 10^s, and sometimes two subsidiary exposures of this kind were given as a check.

The photographs were measured in a position-micrometer by two measurers, being measured by each in reversed positions of the plates to eliminate personality.

Details are given in the case of *β Persei*, *Aldebaran*, and *ξ Ursæ Majoris* to indicate the accuracy obtainable in double star observations from photographs. The main part of the discordances appears to be due to the photographic images themselves and not to error of measurement. Much higher accuracy is obtainable with stars such as *ξ Ursæ Majoris*, *γ Virginis*, &c., than with stars like *Aldebaran*, where the companion is very faint.

β Persei.—These results are obtained from three photographs taken on October 11, October 17, and November 10. On October 11 and October 17 exposures of 20^m were given to the faint companions, and a single exposure of about $\frac{1}{2}^s$ to *Algol*. On November 10, twenty short exposures were given to *Algol* of about $\frac{1}{100}^s$ each at intervals of 1^m during the 20^m exposure on the field, Mr. Davidson's new arrangement of the occulting shutter being used. The sums of the projections of the sides of the two closed triangles ABC and ADE revolved in the directions 0° and 90° are $-0''{\cdot}02$, $-0''{\cdot}05$ for ABC, and $+0''{\cdot}02$, $+0''{\cdot}09$ for ADE, which furnish a sufficient test of the accuracy of the measures.

Aldebaran.—The first set of results is obtained from photographs taken on 1899 February 24, March 9, March 14, and March 15. On two of these photographs a single short exposure was given to the primary, and an exposure of 20^m to the companions. On the other two five short exposures were given to the primary.

The second set of results depends on four photographs taken 1899 November 10, 1900 January 18, January 24, and February 9. These were taken with the occulting shutter after its alteration, and at each minute of the 20^m exposure of the faint stars a short exposure (estimated from the size of the image at $\frac{1}{100}^s$) was given to *Aldebaran*, which thus had a total exposure of about $\frac{1}{5}^s$. The following individual results for A and B are given as showing the accuracy attained in these photographs :—

Date.	Measurer.	Angle.	Discordance from Mean.	Distance.	Discordance from Mean.
1899 Nov. 10	C.D.	109°·84	+0°·10	31″·73	+0″·16
,,	P.M.	109·42	−0·32	31·79	+0·22
1900 Jan. 18	C.D.	109·45	−0·29	31·35	−0·22
,,	P.M.	109·82	+0·08	31·23	−0·34
Jan. 24	C.D.	109·97	+0·23	31·54	−0·03
,,	P.M.	110·25	+0·51	31·60	+0·03
Feb. 9	C.D.	109·95	+0·21	31·65	+0·08
,,	P.M.	109·25	−0·49	31·65	+0·08

ξ Ursæ Majoris.—The separate observations of this star are as follows :—

Date.	Measurer.	Angle.	Discordance from Mean.	Distance.	Discordance from Mean.
		°	°	″	″
1899 Apr. 11	C.D.	159·39	+2·4	1·89	−0·04
"	P.M.	162·03	+5·1	1·95	+0·02
Apr. 17	C.D.	156·35	−0·6	1·95	+0·02
"	P.M.	156·29	−0·7	1·94	+0·01
Apr. 19	C.D.	156·43	−0·5	1·92	−0·01
"	P.M.	157·53	+0·6	1·87	−0·06
May 3	C.D.	152·95	−4·0	1·93	0·00
"	P.M.	154·68	−2·3	1·98	+0·05

Ilford "Empress" plates were used for the first three of these days, and a Hill-Norris' dry collodion "Gazelle" plate on May 3. For the "Empress" plates several exposures were given on each plate, varying from $\frac{1}{8}^s$ to 1^s, and for the "Gazelle" plate from $\frac{1}{2}^s$ to 5^s.

Name of Star.		R.A. 1900·0.	N.P.D. 1900·0.	Mags.	Position Angle.	Distance.	Epoch.	Number of Photos.	Number of Images.
		h m	° ′		°	″			
β Persei	AB	3 2	49 26	... 13·5	155·29	58·24	1899·820	3	3
	AC	...	...	... 14·2	145·58	67·47	1899·820	3	3
	AD	...	...	3 11·0	192·65	81·73	1899·820	3	3
	AE	...	...	... 12·5	185·39	85·69	1899·820	3	3
	BC	...	...	13·5 14·2	101·16	14·05	1899·820	3	3
	DE	...	...	11·0 12·5	119·48	11·26	1899·820	3	3
Aldebaran	AB	4 30	73 42	1·0 14·2	109·80	31·73	1899·182	4	4
	AC	...	...	1·0 10·6	...	117·89	1899·182	4	4
	AC	...	...	..	34·36	...	1899·199	2	2
	AB	...	...	1·0 14·2	109·74	31·57	1900·019	4	4
	AC	...	...	1·0 10·6	34·09	118·27	1900·019	4	4
Castor ...	...	7 28	57 53	2·7 3·7	226·32	6·15	1899·219	1	5
Pollux ...	...	7 39	61 44	1·1 14·3	280·05	29·65	1900·076	2	2
α Cancri...	...	8 53	77 45	4·3 11·2	147·61	11·40	1899·197	1	3
ξ Ursæ Maj.	...	11 13	57 54	4·0 4·9	156·96	1·93	1899·298	4	13
γ Virginis	...	12 36	90 52	3·0 3·0	149·59	5·73	1899·319	4	16
ζ Ursæ Maj.	...	13 20	34 33	2·6 4·2	149·69	14·42	1899·290	1	5
ε Boötis...	...	14 38	62 29	3·0 6·3	326·71	2·60	1899·285	3	11
σ Coronæ Bor.	...	16 11	55 53	5·0 6·1	212·97	4·38	1899·531	1	12
α Herculis	AB	17 10	75 30	3·0 6·1	114·50	4·75	1899·468	2	7
	AC	...	...	3·0 15	334·85	24·07	1899·523	1	1

e of Star.		R.A. 1900·0.	N.P.D. 1900·0.	Mags.		Position Angle.	Distance.	Epoch.	Number of Photos.	Number of Images.
		h m	° ′			°	″			
uchi	...	17 58	98 11	5·0	6·0	256·42	1·71	1899·567	1	8
3 ...	...	18 31	73 6	6·5	7·0	194·48	1·73	1899·567	1	6
: ...	...	18 33	51 19	1	14	285·07	54·36	1899·580	1	1
: ...	...	18 41	50 30	5·0	6·5	11·64	3·08	1899·580	1	7
) ...	...	...	...	5·1	5·2	127·57	2·35	1899·580	1	6
	AB	19 27	83 43	8·1	11·6	148·56	6·80	1899·635	1	1
	AD	...	...	8·1	10·0	254·38	27·04	1899·635	1	1
	AC	...	...	8·1	13·0	327·52	11·43	1899·635	1	1
	AB	19 28	53 32	8·0	12·7	31·25	4·63	1899·775	1	1
	AC	...	...	8·0	8·2	247·89	46·80	1899·705	2	4
	AD	...	...	8·0	8·2	246·23	52·63	1899·705	2	4
	AE	...	...	8·0	12·8	237·63	21·18	1899·705	2	2
	CD	...	...	8·2	8·2	53·20	6·03	1899·705	2	4
...	...	19 50	83 8	6·6	12·5	313·67	12·96	1899·774	2	2
hini	AB	20 35	74 26	4·0	13·5	223·59	29·19	1899·765	2	2
	AC	...	...	4·0	11·1	279·44	43·95	1899·673	3	3
	AD	...	...	4·0	11·5	151·78	47·65	1899·673	3	3
	AE	...	...	4·0	12·7	307·67	51·59	1899·650	2	2
	AF	...	...	4·0	11·0	115·15	79·24	1899·673	3	3
ni	AB	20 43	56 0	5·6	12·2	121·36	10·31	1899·773	2	2
	AC	...	...	5·6	13·3	196·24	12·66	1899·773	2	2
gni	...	21 2	51 46	5·1	6·0	125·36	21·92	1899·798	4	15
	AB	21 35	48 45	7·1	12·7	13·09	6·20	1899·646	3	3
	AC	...	...	7·1	11·0	171·91	13·91	1899·646	3	3
	AD	...	...	7·1	12·1	247·10	17·43	1899·646	3	3
	AE	...	...	7·1	7·2	44·82	29·03	1899·646	3	3
ısi	AC	21 40	64 51	3·9	10·8	300·42	12·86	1899·801	5	6
ɔhei	...	22 2	28 13	5·7	11·5	93·20	20·09	1899·775	2	2
...	...	22 7	83 37	6·8	11·0	337·09	10·58	1899·797	3	3
	AB	22 11	35 51	8·0	10·6	66·07	61·81	1899·792	2	3
	AC	...	...	8·0	11·3	60·50	58·30	1899·792	2	3
	AD	...	...	8·0	13·0	264·23	34·88	1899·792	2	3
	AE	...	...	8·0	14·0	260·94	40·09	1899·789	1	1
	AF	...	...	8·0	13·0	112·65	33·54	1899·792	2	2
	BC	...	...	10·6	11·3	303·49	7·07	1899·792	2	3
	DE	...	...	13·0	14·0	241·49	6·07	1899·789	1	1

al Observatory, Greenwich :
1900 *April* 10.

Cometary Observations at the Liverpool Observatory. By W. E. Plummer.

Comet 1898 *X* (*Brooks, October* 20).

Greenwich Mean Time of Observation. 1899.	h m s	☄ − ✱ R.A. m s	No. of Comparisons.	Apparent R.A. of ☄. h m s	☄ − ✱ Declination. ′ ″	No. of Comparisons.	Apparent Declination of ☄. ° ′ ″	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
Oct. 24	10 2 14·5	+5 59·67	10	15 55 59·38	−7 23·2	5	+50 36 9·6	+9·6394	−0·8421	1
	10 2 14·5	−3 6·90	10	15 55 59·51	+3 10·2	5	+50 36 8·1	+9·6394	−0·8421	2
30	7 7 22·4	−1 39·18	Ret.	17 0 42·06	+5 52·1	Ret.	+33 26 43·4	+9·6058	−0·7041	3
31	6 58 4·7	−1 14·61	10	17 7 45·22	+2 33·3	6	+30 44 2·1	+9·5840	−0·7122	4
Nov. 1	7 3 27·0	−1 15·16	10	17 14 8·30	−1 53·0	5	+28 6 3·2	+9·5761	−0·7335	5
1	7 3 27·0	−1 30·38	10	17 14 8·32	−5 19·6	5	+28 6 4·9	+9·5761	−0·7335	6
3	6 50 50·1	+ 2·88	Ret.	17 24 56·14	−4 54·5	Ret.	+23 13 54·5	+9·5473	−0·7514	7
6	6 56 34·3	− 40·82	12	17 37 38·66	−2 7·7	6	+16 46 29·6	+9·5332	−0·7912	8
7	6 8 40·5	+ 0·62	Ret.	17 41 0·78	−1 23·4	Ret.	+14 55 4·5	+9·4817	−0·7816	9
10	6 4 33·6	+ 39·47	10	17 49 46·21	−3 54·6	5	+ 9 44 33·6	+9·4731	−0·8087	10
10	6 4 33·6	−1 26·11	8	17 49 46·13	−1 46·0	5	+ 9 44 34·0	+9·4731	−0·8087	11

October 24.—The comet is a fairly bright object, with well-defined centre, which makes the observation easy.
October 30.—The comet seen through some haze with difficulty. The observation is somewhat uncertain.
November 7.—The comet is bright, but very ill-defined, and the observations lack coherence.

Comet 1899 *I* (*Swift, March* 4).

1899.	Greenwich Mean Time of Observation. h m s	☄ − ★ R.A. m s	No. of Comparisons.	Apparent R.A. of ☄. h m s	☄ − ★ Declination. ′ ″	No. of Comparisons.	Apparent Declination of ☄. ° ′ ″	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
Mar. 7	7 2 59·5	−2 40·70	3	3 33 24·63	+ 1 17·9	3	−23 13 10·7	+9·3358	−0·9121	12
11	7 13 4·6	−1 8·42	2	3 14 58·34	+ 2 38·9	2	−17 50 34·0	+9·4198	−0·8935	13
12	7 15 2·9	−1 39·36	3	3 10 53·80	+ 5 21·0	3	−16 35 51·6	+9·4666	−0·8831	14
14	7 9 6·0	+ 43·37	5	3 3 16·55	− 5 26·1	5	−14 14 5·2	+9·4460	−0·8830	15
15	7 11 3·1	+2 10·89	5	2 59 39·48	− 4 48·0	5	−13 6 19·4	+9·4582	−0·8804	16
15	7 11 3·1	− 51·09	5	2 59 39·33	+ 49·7	5	−13 6 16·8	+9·4582	−0·8804	17
16	7 12 51·7	+3 23·28	Ret.	2 56 10·10	+ 8 17·0	Ret.	−12 0 44·4	+9·4689	−0·8752	18
17	7 13 22·5	+ 43·74	2	2 52 46·58	−10 22·6	2	−10 57 15·4	+9·4773	−0·8719	19
17	7 13 27·9	+3 31·70	5	2 52 46·51	− 5 58·6	5	−10 57 14·6	+9·4773	−0·8719	20
18	7 20 59·3	+1 32·32	5	2 49 27·92	− 4 8·3	5	− 9 55 32·7	+9·4929	−0·8673	21
20	7 22 6·8	+7 38·38	Ret.	2 43 4·46	− 5 49·1	Ret.	− 7 57 44·9	+9·5055	−0·8618	22
22	7 24 13·7	−6 33·54	Ret.	2 36 55·38	+ 2 3·7	Ret.	− 6 7 29·4	+9·5169	−0·8570	23
May 16	11 22 54·0	+0 39·22	5	22 53 5·16	+ 0 57·7	5	+40 22 30·1	−9·5952	−0·8525	24
18	11 5 36·3	−1 15·54	6	22 34 51·17	− 9 40·5	4	+43 35 11·3	−9·6267	−0·8357	25
18	11 5 36·3	+ 29·05	6	22 34 51·43	−11 55·4	6	+43 35 12·1	−9·6267	−0·8357	26
26	10 16 40·5	−1 1·89	5	20 29 11·40	− 59·9	5	+55 36 16·4	−9·7925	−0·6149	27
27	9 57 29·8	+ 58·57	4	20 6 17·47	+ 4 56·6	4	+56 28 0·3	−9·8025	−0·5893	28
29	11 6 44·2	−3 3·72	5	19 15 23·86	− 6 32·3	5	+57 20 35·0	−9·7411	−0·1600	29
29	11 6 44·2	+3 13·61	5	19 15 23·49	−11 6·9	5	+57 20 38·6	−9·7411	−0·1600	30
30	10 22 0·4	−1 14·88	6	18 50 49·16	− 4 11·4	6	+57 17 11·7	−9·7582	−0·2378	31
31	10 19 13·1	−4 57·28	5	18 25 55·74	− 3 15·7	5	+56 54 44·7	−9·7240	−0·1296	32
31	10 19 13·1	+2 25·14	5	18 25 55·72	− 39·1	5	+56 54 47·1	−9·7240	−0·1296	33

1899.	Greenwich Mean Time of Observation.	☄ – ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ – ✱ Declination.	Comparisons.	Declination of ☄.	of Parallax in α.	in δ.	of Comparison.
	h m s	m s		h m s	′ ″		° ′ ″			
June 1	9 56 58·3	+1 18·65	3	18 2 22·33	− 7 0·7	3	+56 14 54·7	−9·7094	−0·1311	34
2	9 50 11·6	−2 6·19	5	17 39 58·25	+ 6 55·9	5	+55 18 46·9	−9·6698	−0·0746	35
2	9 50 11·6	−1 24·31	5	17 39 57·99	+ 6 23·1	5	+55 18 47·0	−9·6698	−0·0746	36
4	10 11 44·0	+1 0·31	4	16 59 58·70	+ 2 37·5	4	+52 47 29·7	−9·4874	−9·8461	37
5	10 10 29·8	−5 33·28	5	16 42 55·27	+ 1 22·8	5	+51 19 15·6	−9·4032	−9·8645	38
5	10 10 29·8	+ 45·15	5	16 42 55·13	+ 1 38·3	5	+51 19 16·1	−9·4032	−9·8645	39
6	10 14 3·7	+1 54·00	6	16 27 34·80	− 7 53·5	6	+49 45 22·1	−9·2956	−9·9066	40
8	10 24 41·4	−7 36·73	6	16 1 38·70	+ 1 10·9	6	+46 29 42·0	−8·9564	−0·0371	41
8	10 24 41·4	+1 56·62	6	16 1 38·68	+10 41·0	6	+46 29 40·9	−8·9564	−0·0371	42
9	10 3 32·5	+2 20·51	5	15 50 57·44	− 6 51·0	5	+44 53 2·7	−9·0078	−0·1313	43
9	10 3 32·5	+1 27·28	5	15 50 57·39	+ 3 45·4	5	+44 53 3·6	−9·0078	−0·1313	44
10	10 45 11·2	−5 5·52	Ret.	15 41 0·81	+ 4 13·1	Ret.	+43 13 18·3	+8·2304	−0·1838	45
12	10 36 4·0	−1 45·00	6	15 24 42·71	− 8 38·5	6	+40 6 33·3	+8·6720	−0·2993	46
12	10 36 4·0	−1 57·35	6	15 24 42·63	+ 4 12·4	6	+40 6 34·6	+8·6720	−0·2993	47
13	10 21 46·1	−2 43·51	Ret.	15 17 51·60	+ 5 13·4	Ret.	+38 38 4·2	+8·5843	−0·3409	48
14	10 48 59·9	+ 19·83	Ret.	15 11 31·72	− 2 4·5	Ret.	+37 10 8·0	+9·0363	−0·4025	49
15	11 6 22·0	+1 42·16	Ret.	15 5 50·90	+ 9 1·2	Ret.	+35 46 19·2	+9·1912	−0·4531	50
16	10 49 55·3	−2 13·40	Ret.	15 0 51·80	+ 6 35·0	Ret.	+34 27 46·0	+9·1451	−0·4752	51

March 7.—The comet was seen long before any star of comparison could be seen in the light sky of twilight owing to the low altitude; the definition was very unsatisfactory.

March 11–22.—The conditions for seeing very unfavourable; a correction for difference of refraction has been applied.

May 16.—The comet is bright but diffused.

May 27.—Observations interrupted by clouds.

June 10.—Clouds; sky very light.

June 13.—Seen with difficulty.

Tuttle's Comet.

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in α.	in δ.	Star of Comparison.
1899.	h m s	m s		h m s	′ ″		° ′ ″			
Apr. 4	8 11 22·0	+0 19·45	Ret.	3 10 2·37	+ 9 1·2	Ret.	+22 59 26·5	+9·5791	−0·8076	52
10	8 28 16·3	−0 56·81	Ret.	3 32 12·41	+ 6 20·6	Ret.	+20 41 36·0	+9·5737	−0·8178	53

April 4.—The comet appeared as a small round nebula of about one minute in diameter, in which neither condensation nor nucleus could be detected.

April 10.—The comet is at the limit of visibility, and cannot be profitably observed with this instrument.

Comet 1899 *IV* (*Tempel II.*)

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in R.A.	in δ.	No. of Reference.
1899.	h m s	m s		h m s	′ ″		° ′ ″			
July 26	10 39 12 1	+0 56·76	Ret.	20 46 40·49	+2 18·6	Ret.	−21 21 35·7	−9·2816	−0·9136	54
28	12 19 51 2	−1 58 57	Ret.	20 49 8·26	−7 2·2	Ret.	−22 30 18·6	−8·4073	−0·9296	55
30	11 6 30·3	−4 10·63	Ret.	20 51 27·27	−6 22·1	Ret.	−23 34 27·6	−9·1361	−0·9247	56
Aug. 1	11 21 55·8	+2 37 26	Ret.	20 53 50·12	−4 52·0	Ret.	−24 39 32·4	−9·0188	−0·9286	57

July 26.—The comet faint and ill-defined; but seen no better later in the evening, owing to the increase of moonlight.

July 30 and August 1.—The places are very doubtful, and are hardly likely to be of use in future discussion.

1899.	Greenwich Mean Time of Observation. h m s	☄ – ✱ R.A. m s	No. of Comparisons.	Apparent R.A. of ☄. h m s	☄ – ✱ Declination. ′ ″	No. of Comparisons.	Apparent Declination of ☄. ° ′ ″	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
June 1	9 56 58·3	+1 18·65	3	18 2 22·33	− 7 0·7	3	+56 14 54·7	−9·7094	−0·1311	34
2	9 50 11·6	−2 6·19	5	17 39 58·25	+ 6 55·9	5	+55 18 46·9	−9·6698	−0·0746	35
2	9 50 11·6	−1 24·31	5	17 39 57·99	+ 6 23·1	5	+55 18 47·0	−9·6698	−0·0746	36
4	10 11 44·0	+1 0·31	4	16 59 58·70	+ 2 37·5	4	+52 47 29·7	−9·4874	−9·8461	37
5	10 10 29·8	−5 33·28	5	16 42 55·27	+ 1 22·8	5	+51 19 15·6	−9·4032	−9·8645	38
5	10 10 29·8	+ 45·15	5	16 42 55·13	+ 1 38·3	5	+51 19 16·1	−9·4032	−9·8645	39
6	10 14 3·7	+1 54·00	6	16 27 34·80	− 7 53·5	6	+49 45 22·1	−9·2956	−9·9066	40
8	10 24 41·4	−7 36·73	6	16 1 38·70	+ 1 10·9	6	+46 29 42·0	−8·9564	−0·0371	41
8	10 24 41·4	+1 56·62	6	16 1 38·68	+10 41·0	6	+46 29 40·9	−8·9564	−0·0371	42
9	10 3 32·5	+2 20·51	5	15 50 57·44	− 6 51·0	5	+44 53 2·7	−9·0078	−0·1313	43
9	10 3 32·5	+1 27·28	5	15 50 57·39	+ 3 45·4	5	+44 53 3·6	−9·0078	−0·1313	44
10	10 45 11·2	−5 5·52	Ret.	15 41 0·81	+ 4 13·1	Ret.	+43 13 18·3	+8·2304	−0·1838	45
12	10 36 4·0	−1 45·00	6	15 24 42·71	− 8 38·5	6	+40 6 33·3	+8·6720	−0·2993	46
12	10 36 4·0	−1 57·35	6	15 24 42·63	+ 4 12·4	6	+40 6 34·6	+8·6720	−0·2993	47
13	10 21 46·1	−2 43·51	Ret.	15 17 51·60	+ 5 13·4	Ret.	+38 38 4·2	+8·5843	−0·3409	48
14	10 48 59·9	+ 19·83	Ret.	15 11 31·72	− 2 4·5	Ret.	+37 10 8·0	+9·0363	−0·4025	49
15	11 6 22·0	+1 42·16	Ret.	15 5 50·90	+ 9 1·2	Ret.	+35 46 19·2	+9·1912	−0·4531	50
16	10 49 55·3	−2 13·40	Ret.	15 0 51·80	+ 6 35·0	Ret.	+34 27 46·0	+9·1451	−0·4752	51

March 7.—The comet was seen long before any star of comparison could be seen in the light sky of twilight owing to the low altitude; the definition was very unsatisfactory.

March 11–22.—The conditions for seeing very unfavourable; a correction for difference of refraction has been applied.

May 16.—The comet is bright but diffused.

May 27.—Observations interrupted by clouds.

June 10.—Clouds; sky very light.

June 13.—Seen with difficulty.

Tuttle's Comet.

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
1899.	h m s	m s		h m s	′ ″		° ′ ″			
Apr. 4	8 11 22·0	+0 19·45	Ret.	3 10 2·37	+ 9 1·2	Ret.	+22 59 26·5	+9·5791	−0·8076	52
10	8 28 16·3	−0 56·81	Ret.	3 32 12·41	+ 6 20·6	Ret.	+20 41 36·0	+9·5737	−0·8178	53

April 4.—The comet appeared as a small round nebula of about one minute in diameter, in which neither condensation nor nucleus could be detected.

April 10.—The comet is at the limit of visibility, and cannot be profitably observed with this instrument.

Comet 1899 *IV* (*Tempel II.*)

Greenwich Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in R.A.	Log. Factor of Parallax in δ.	No. of Reference.
1899.	h m s	m s		h m s	′ ″		° ′ ″			
July 26	10 39 12·1	+0 56·76	Ret.	20 46 40·49	+2 18·6	Ret.	−21 21 35·7	−9·2816	−0·9136	54
28	12 19 51·2	−1 58·57	Ret.	20 49 8·26	−7 2·2	Ret.	−22 30 18·6	−8·4073	−0·9296	55
30	11 6 30·3	−4 10·63	Ret.	20 51 27·27	−6 22·1	Ret.	−23 34 27·6	−9·1361	−0·9247	56
Aug. 1	11 21 55·8	+2 37·26	Ret.	20 53 50·12	−4 52·0	Ret.	−24 39 32·4	−9·0188	−0·9286	57

July 26.—The comet faint and ill-defined; but seen no better later in the evening, owing to the increase of moonlight.

July 30 and August 1.—The places are very doubtful, and are hardly likely to be of use in future discussion.

Cometary Observations at the Liverpool Observatory. By W. E. Plummer.

Comet 1898 *X* (*Brooks, October* 20).

Greenwich Mean Time of Observation.		☄ — ✱ R.A.	No. of Comparisons.	Apparent R.A. of ☄.	☄ — ✱ Declination.	No. of Comparisons.	Apparent Declination of ☄.	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
1899.	h m s	m s		h m s	′ ″		° ′ ″			
Oct. 24	10 2 14·5	+5 59·67	10	15 55 59·38	−7 23·2	5	+50 36 9·6	+9·6394	−0·8421	1
	10 2 14·5	−3 6·90	10	15 55 59·51	+3 10·2	5	+50 36 8·1	+9·6394	−0·8421	2
30	7 7 22·4	−1 39·18	Ret.	17 0 42·06	+5 52·1	Ret.	+33 26 43·4	+9·6058	−0·7041	3
31	6 58 4·7	−1 14·61	10	17 7 45·22	+2 33·3	6	+30 44 2·1	+9·5840	−0·7122	4
Nov. 1	7 3 27·0	−1 15·16	10	17 14 8·30	−1 53·0	5	+28 6 3·2	+9·5761	−0·7335	5
1	7 3 27·0	−1 30·38	10	17 14 8·32	−5 19·6	5	+28 6 4·9	+9·5761	−0·7335	6
3	6 50 50·1	+ 2·88	Ret.	17 24 56·14	−4 54·5	Ret.	+23 13 54·5	+9·5473	−0·7514	7
6	6 56 34·3	− 40·82	12	17 37 38·66	−2 7·7	6	+16 46 29·6	+9·5332	−0·7912	8
7	6 8 40·5	+ 0·62	Ret.	17 41 0·78	−1 23·4	Ret.	+14 55 4·5	+9·4817	−0·7816	9
10	6 4 33·6	+ 39·47	10	17 49 46·21	−3 54·6	5	+ 9 44 33·6	+9·4731	−0·8087	10
10	6 4 33·6	−1 26·11	8	17 49 46·13	−1 46·0	5	+ 9 44 34·0	+9·4731	−0·8087	11

October 24.—The comet is a fairly bright object, with well-defined centre, which makes the observation easy.
October 30.—The comet seen through some haze with difficulty. The observation is somewhat uncertain.
November 7.—The comet is bright, but very ill-defined, and the observations lack coherence.

Comet 1899 *I* (*Swift, March* 4).

Date 1899.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	No. of Reference.
Mar. 7	A.We., No. 2019	3 36 4·41	+0·92	−23 14 21·9	− 6·7	12
11	A.We., No. 1819; Paris, No. 3997	3 16 5·93	+0·83	−17 53 8·6	− 4·3	13
12	A.We., No. 1791	3 12 32·37	+0·81	−16 41 8·7	− 3·9	14
14	Porter (12), No. 214; Stone, No. 744	3 2 32·40	+0·78	−14 8 36·3	− 2·8	15
15	Stone, No. 727	2 57 27·83	+0·76	−13 1 29·1	− 2·3	16
15	W.B. II., No. 1038	3 0 29·65	+0·77	−13 7 4·1	− 2·4	17
16	W.B. II., No. 886; La_2, No. 230	2 52 46·07	+0·75	−12 8 59·5	− 1·9	18
17	W.B. II., No. 875; La_2, No. 229	2 52 2·09	+0·75	−10 46 51·3	− 1·5	19
17	Stone, Rad. Cat., No. 690	2 49 14·06	+0·75	−10 51 14·4	− 1·6	20
18	Paris, No. 3528; Stone, No. 684	2 47 54·87	+0·73	− 9 51 23·4	− 1·0	21
20	Stone, Rad. Cat., No. 636	2 35 25·38	+0·70	− 7 51 55·5	− 0·3	22
22	Stone, Rad. Cat., No. 668	2 43 28·23	+0·69	− 6 9 33·3	+ 0·2	23
May 16	A.G.Z. Bonn Cat., No. 17271	22 52 24·48	+1·46	+40 21 35·0	− 2·6	24
18	11 Lacertæ, A.G.Z. Bonn Cat., No. 16991	22 36 5·17	+1·54	+43 44 55·5	− 3·7	25
18	A.G.Z. Bonn Cat., No. 16955	22 34 20·84	+1·54	+43 47 11·2	− 3·7	26
26	A.G.Z. Helsingfors, No. 11465	20 30 10·99	+2·30	+55 37 23·7	− 7·4	27
27	A.G.Z. Helsingfors, No. 11116	20 5 16·47	+2·43	+56 23 11·1	− 7·4	28
29	A.G.Z. Helsingfors, No. 10399	19 18 24·81	+2·77	+57 27 14·7	− 7·4	29
29	Radcliffe 1st Cat., No. 4148	19 12 7·10	+2·78	+57 31 52·9	− 7·4	30
30	A.G.Z. Helsingfors, No. 10059	18 52 1·15	+2·89	+57 21 30·2	− 7·1	31

1899.	Greenwich Mean Time of Observation. h m s	☌−✱ R.A. m s	No. of Comparisons.	Apparent R.A. of ☌. h m s	☌−✱ Declination. ′ ″	No. of Comparisons.	Apparent Declination of ☌. ° ′ ″	Log. Factor of Parallax in α.	Log. Factor of Parallax in δ.	Star of Comparison.
June 1	9 56 58·3	+1 18·65	3	18 2 22·33	− 7 0·7	3	+56 14 54·7	−9·7094	−0·1311	34
2	9 50 11·6	−2 6·19	5	17 39 58·25	+ 6 55·9	5	+55 18 46·9	−9·6698	−0·0746	35
2	9 50 11·6	−1 24·31	5	17 39 57·99	+ 6 23·1	5	+55 18 47·0	−9·6698	−0·0746	36
4	10 11 44·0	+1 0·31	4	16 59 58·70	+ 2 37·5	4	+52 47 29·7	−9·4874	−9·8461	37
5	10 10 29·8	−5 33·28	5	16 42 55·27	+ 1 22·8	5	+51 19 15·6	−9·4032	−9·8645	38
5	10 10 29·8	+ 45·15	5	16 42 55·13	+ 1 38·3	5	+51 19 16·1	−9·4032	−9·8645	39
6	10 14 3·7	+1 54·00	6	16 27 34·80	− 7 53·5	6	+49 45 22·1	−9·2956	−9·9066	40
8	10 24 41·4	−7 36·73	6	16 1 38·70	+ 1 10·9	6	+46 29 42·0	−8·9564	−0·0371	41
8	10 24 41·4	+1 56·62	6	16 1 38·68	+10 41·0	6	+46 29 40·9	−8·9564	−0·0371	42
9	10 3 32·5	+2 20·51	5	15 50 57·44	− 6 51·0	5	+44 53 2·7	−9·0078	−0·1313	43
9	10 3 32·5	+1 27·28	5	15 50 57·39	+ 3 45·4	5	+44 53 3·6	−9·0078	−0·1313	44
10	10 45 11·2	−5 5·52	Ret.	15 41 0·81	+ 4 13·1	Ret.	+43 13 18·3	+8·2304	−0·1838	45
12	10 36 4·0	−1 45·00	6	15 24 42·71	− 8 38·5	6	+40 6 33·3	+8·6720	−0·2993	46
12	10 36 4·0	−1 57·35	6	15 24 42·63	+ 4 12·4	6	+40 6 34·6	+8·6720	−0·2993	47
13	10 21 46·1	−2 43·51	Ret.	15 17 51·60	+ 5 13·4	Ret.	+38 38 4·2	+8·5843	−0·3409	48
14	10 48 59·9	+ 19·83	Ret.	15 11 31·72	− 2 4·5	Ret.	+37 10 8·0	+9·0363	−0·4025	49
15	11 6 22·0	+1 42·16	Ret.	15 5 50·90	+ 9 1·2	Ret.	+35 46 19·2	+9·1912	−0·4531	50
16	10 49 55·3	−2 13·40	Ret.	15 0 51·80	+ 6 35·0	Ret.	+34 27 46·0	+9·1451	−0·4752	51

March 7.—The comet was seen long before any star of comparison could be seen in the light sky of twilight owing to the low altitude; the definition was very unsatisfactory.

March 11–22.—The conditions for seeing very unfavourable; a correction for difference of refraction has been applied.

May 16.—The comet is bright but diffused.

May 27.—Observations interrupted by clouds.

Date 1899.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	No. of Reference.
	Tuttle's Comet.					
April 4	A.G Z. Berlin B. Zones, No. 953	3 9 42·03	+0·89	+22 50 19·9	+ 5·4	52
10	A G Z. Berlin B. Zones, No. 1084	3 33 8·30	+0·92	+20 35 11·1	+ 4·3	53
	Tempel II., Comet, 1899 *IV.*					
July 26	Washington Zones, 1889; Frisby, 9334	20 45 39·09	+4·64	−21 24 12·5	+18·2	54
28	Radcliffe Cat., Stone, No. 5636	20 51 2·17	+4·66	−22 23 35·0	+18·6	55
30	Radcliffe Cat., Stone, No. 5656	20 55 33·18	+4·72	−23 28 24·4	+18·9	56
Aug. 1	Washington Zones, 1889, Frisby, No. 9378	20 51 8·08	+4·78	−24 34 59·2	+18·8	57
	Comet 1899 *V* (*Giacobini*).					
Oct. 4	Paris Catalogue, No. 20771	16 28 39·67	+2·70	− 3 34 39·5	− 1·1	58
8	Munich Neue Annalen, Bd. I., No. 12965	16 38 40·76	+2·69	− 2 26 26·3	− 0·1	59
9	Göttingen No. 2, No. 4097	16 46 0·71	+2·67	− 2 2 32·0	+ 0·7	60

Liverpool Observatory: 1900 *April* 10.

Date	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	No. of Reference.
1899.		h m s	s	° ′ ″	″	
31	45 Draconis; Helsingfors, No. 9856	18 30 50·02	+3·00	+56 58 7·1	− 6·7	32
31	A.G.Z. Helsingfors, No. 9789	18 23 27·57	+3·01	+56 55 32·9	− 6·7	33
June 1	Bonn, Vol. VI. +56°, No. 2058	18 1 0·56	+3·12	+56 22 1·6	− 6·2	34
2	A.G.Z. Helsingfors, No. 9436	17 42 1·25	+3·19	+55 11 56·8	− 5·8	35
2	A.G.Z. Helsingfors, No. 9430	17 41 19·11	+3·19	+55 12 29·7	− 5·8	36
4	A.G.Z. Cambridge Cat., No. 5133	16 58 55·12	+3·27	+52 44 57·1	− 4·9	37
5	A.G.Z. Cambridge Cat., No. 5092	16 48 25·27	+3·28	+51 17 57·3	− 4·5	38
5	A.G.Z. Cambridge Cat., No. 5070	16 42 6·69	+3·29	+51 17 42·3	− 4·5	39
6	A.G.Z. Cambridge Cat., No. 5008	16 25 37·50	+3·30	+49 53 19·8	− 4·2	40
8	A.G.Z. Bonn Cat., No. 10402	16 9 12·15	+3·28	+46 28 34·9	− 3·8	41
8	Bonn, Vol. VI. +46°, No. 2142	15 59 38·78	+3·28	+46 19 3·7	− 3·8	42
9	A.G.Z. Bonn Cat., No. 10192	15 48 33·66	+3·27	+44 59 57·4	− 3·7	43
9	A.G.Z. Bonn Cat., No. 10201	15 49 26·84	+3·27	+44 49 21·9	− 3·7	44
10	A.G.Z. Bonn Cat., No. 10174	15 46 3·14	+3·26	+43 9 8·9	− 3·7	45
12	A.G.Z. Bonn Cat., No. 9984	15 26 24·47	+3·24	+40 15 15·4	− 3·6	46
12	Radcliffe, No. 3395; A.G.Z. Bonn Cat., No. 9987	15 26 36·75	+3·23	+40 2 25·8	− 3·6	47
13	Paris Cat., No. 19126; A.G.Z. Lund Zone 6	15 20 31·89	+3·22	+38 32 53·9	− 3·6	48
14	W.B. XI. No. 199; A.G.Z. Lund Zones	15 11 8·69	+3·20	+37 12 16·2	− 3·7	49
15	Rü, No 4958; A.G.Z. Lund Zones	15 4 [illegible]·56	+3·18	+35 37 21·8	− 3·8	50
16	A.G.Z. Leiden Zones, No. 42	15 3 2·03	+3·17	+34 21 14·9	− 3·9	51

Comet 1899 *I* (*Swift, March* 4).

Date	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	No. of Reference.
1899.		h m s	s	° ′ ″	″	
Mar. 7	A.We., No. 2019	3 36 4·41	+0·92	−23 14 21·9	− 6·7	12
11	A.We., No. 1819; Paris, No. 3997	3 16 5·93	+0·83	−17 53 8·6	− 4·3	13
12	A.We., No. 1791	3 12 32·37	+0·81	−16 41 8·7	− 3·9	14
14	Porter (12), No. 214; Stone, No. 744	3 2 32·40	+0·78	−14 8 36·3	− 2·8	15
15	Stone, No. 727	2 57 27·83	+0·76	−13 1 29·1	− 2·3	16
15	W.B. II., No. 1038	3 0 29·65	+0·77	−13 7 4·1	− 2·4	17
16	W.B. II., No. 886; La$_2$, No. 230	2 52 46·07	+0·75	−12 8 59·5	− 1·9	18
17	W.B. II., No. 875; La$_2$, No. 229	2 52 2·09	+0·75	−10 46 51·3	− 1·5	19
17	Stone, Rad. Cat., No. 690	2 49 14·06	+0·75	−10 51 14·4	− 1·6	20
18	Paris, No. 3528; Stone, No. 684	2 47 54·87	+0·73	− 9 51 23·4	− 1·0	21
20	Stone, Rad. Cat., No. 636	2 35 25·38	+0·70	− 7 51 55·5	− 0·3	22
22	Stone, Rad. Cat., No. 668	2 43 28·23	+0·69	− 6 9 33·3	+ 0·2	23
May 16	A.G.Z. Bonn Cat., No. 17271	22 52 24·48	+1·46	+40 21 35·0	− 2·6	24
18	11 Lacertæ, A.G.Z. Bonn Cat., No. 16991	22 36 5·17	+1·54	+43 44 55·5	− 3·7	25
18	A.G.Z. Bonn Cat., No. 16955	22 34 20·84	+1·54	+43 47 11·2	− 3·7	26
26	A.G.Z. Helsingfors, No. 11465	20 30 10·99	+2·30	+55 37 23·7	− 7·4	27
27	A.G.Z. Helsingfors, No. 11116	20 5 16·47	+2·43	+56 23 11·1	− 7·4	28
29	A.G.Z. Helsingfors, No. 10399	19 18 24·81	+2·77	+57 27 14·7	− 7·4	29
29	Radcliffe 1st Cat., No. 4148	19 12 7·10	+2·78	+57 31 52·9	− 7·4	30
30	A.G.Z. Helsingfors, No. 10059	18 52 1·15	+2·89	+57 21 30·2	− 7·1	31

Date	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year.	Correction to Mean R.A.	Mean Declination. Equinox of Year.	Correction to Mean Declination.	No. of Reference.
1899.		h m s	s	° ′ ″	″	
31	45 Draconis; Helsingfors, No. 9856	18 30 50·02	+3·00	+56 58 7·1	− 6·7	32
31	A.G.Z. Helsingfors, No. 9789	18 23 27·57	+3·01	+56 55 32·9	− 6·7	33
June 1	Bonn, Vol. VI. +56°, No. 2058	18 1 0·56	+3·12	+56 22 1·6	− 6·2	34
2	A.G.Z. Helsingfors, No. 9436	17 42 1·25	+3·19	+55 11 56·8	− 5·8	35
2	A.G.Z. Helsingfors, No. 9430	17 41 19·11	+3·19	+55 12 29·7	− 5·8	36
4	A.G.Z. Cambridge Cat., No. 5133	16 58 55·12	+3·27	+52 44 57·1	− 4·9	37
5	A.G.Z. Cambridge Cat., No. 5092	16 48 25·27	+3·28	+51 17 57·3	− 4·5	38
5	A.G.Z. Cambridge Cat., No. 5070	16 42 6·69	+3·29	+51 17 42·3	− 4·5	39
6	A.G.Z. Cambridge Cat., No. 5008	16 25 37·50	+3·30	+49 53 19·8	− 4·2	40
8	A.G.Z. Bonn Cat., No. 10402	16 9 12·15	+3·28	+46 28 34·9	− 3·8	41
8	Bonn, Vol. VI. +46°, No. 2142	15 59 38·78	+3·28	+46 19 3·7	− 3·8	42
9	A.G.Z. Bonn Cat., No. 10192	15 48 33·66	+3·27	+44 59 57·4	− 3·7	43
9	A.G.Z. Bonn Cat., No. 10201	15 49 26·84	+3·27	+44 49 21·9	− 3·7	44
10	A.G.Z. Bonn Cat., No. 10174	15 46 3·14	+3·26	+43 9 8·9	− 3·7	45
12	A.G.Z. Bonn Cat., No. 9984	15 26 24·47	+3·24	+40 15 15·4	− 3·6	46
12	Radcliffe, No. 3395; A.G.Z. Bonn Cat., No. 9987	15 26 36·75	+3·23	+40 2 25·8	− 3·6	47
13	Paris Cat., No. 19126; A.G.Z. Lund Zone 6	15 20 31·89	+3·22	+38 32 53·9	− 3·6	48
14	W.B. XI. No. 199; A.G.Z. Lund Zones	15 11 8·69	+3·20	+37 12 16·2	− 3·7	49
15	Rü, No 4958; A.G.Z. Lund Zones	15 4 [illegible]·56	+3·18	+35 37 21·8	− 3·8	50
16	A.G.Z. Leiden Zones, No. 42	15 3 2·03	+3·17	+34 21 14·9	− 3·9	51

Tuttle's Comet.

Date 1899.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	No. of Reference.
April 4	A.G Z. Berlin B. Zones, No. 953	3 9 42·03	+0·89	+22 50 19·9	+ 5·4	52
10	A G Z. Berlin B. Zones, No. 1084	3 33 8·30	+0·92	+20 35 11·1	+ 4·3	53

Tempel II., Comet, 1899 IV.

Date 1899.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	No. of Reference.
July 26	Washington Zones, 1889; Frisby, 9334	20 45 39·09	+4·64	−21 24 12·5	+18·2	54
28	Radcliffe Cat., Stone, No. 5636	20 51 2·17	+4·66	−22 23 35·0	+18·6	55
30	Radcliffe Cat., Stone, No. 5656	20 55 33·18	+4·72	−23 28 24·4	+18·9	56
Aug. 1	Washington Zones, 1889, Frisby, No. 9378	20 51 8·08	+4·78	−24 34 59·2	+18·8	57

Comet 1899 *V (Giacobini).*

Date 1899.	Star's Designation or Authority for Places.	Mean R.A. Equinox of Year. h m s	Correction to Mean R.A. s	Mean Declination. Equinox of Year. ° ′ ″	Correction to Mean Declination. ″	No. of Reference.
Oct. 4	Paris Catalogue, No. 20771	16 28 39·67	+2·70	− 3 34 39·5	− 1·1	58
8	Munich Neue Annalen, Bd. I., No. 12965	16 38 40·76	+2·69	− 2 26 26·3	− 0·1	59
9	Göttingen No. 2, No. 4097	16 46 0·71	+2·67	− 2 2 32·0	+ 0·7	60

Liverpool Observatory: 1900 *April* 10.

Errata in Mr Ellis's Paper.

Page 153, line 5 of table, *for* 188 *read* 187.
" " 6 " *for* 174 *read* 175.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. MAY 11, 1900. No. 8

E. B. KNOBEL, Esq., PRESIDENT, in the Chair.

Alexander Foote, J.P., F.S.A. Scot., 111 Warwick Road, Earl's Court, S.W., and Mall Park, Montrose, Scotland; and

Désiré Ernest Lebon, Agrégé de l'Université, Professeur de Mathématiques au Lycée Charlemagne, 4 bis, rue des Écoles, Paris,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Arthur H. Baker, B.A., Headmaster Basnett Road Board School, Lavender Hill, S.W.; and 28 Cautley Avenue, Clapham Common, S.W. (proposed by Thomas Lewis);

William Henry Colegrave, Master Mariner (P. & O. Service), Little Tew, Enstone, Oxford (proposed by Duncan Forbes); and

Guy François Comte Meredyth de Miremont, Orleans Club, St. James's, London, S.W. (proposed by Duncan Forbes).

Fifty-two presents were announced as having been received since the last meeting, including amongst others :—

F. K. Ginzel, Specieller Kanon der Sonnen- und Mondfinsternisse, presented by the author; Harvard Observatory, Annals,

P P

vol. xliv. (E. C. Pickering, Revision of the Harvard Photometry), presented by the Observatory; Royal Observatory, Lisbon, O Eclipse de Sol de 1900 Maio 28, presented by the Observatory; Facsimile of Captain Cook's original Observation of the Transit of *Venus*, 1769 (lantern slide), presented by Rev. E. Ledger.

On the Alleged Rotation of the Spiral Nebula Messier 51 *Canum Venaticorum*. By H. H. Turner, M.A., F.R.S., Savilian Professor.

In his recently published second volume of *Photographs of Stars, Star Clusters, and Nebulæ* Dr. Isaac Roberts gives measures of a photograph of M 51, taken in 1898, and a comparison with Lord Rosse's measures in 1872–74, whence he suggests that the nebula has rotated round its central nucleus through over 100′ in 47 years. As a movement of this magnitude in a nebula, if well established, is naturally of the first importance, I wrote to Dr. Roberts asking for particulars as to his determination of the zero of position-angle. He very kindly sent me full particulars and a copy of the original negative. On this copy I found that there were three Groombridge stars, also contained therefore in the Radcliffe (1845·0) Catalogue; and that these have been recently observed at Greenwich and will appear in the forthcoming Ten-year (1890·0) Catalogue. Places of these stars, which were kindly supplied by the Astronomer Royal, give an independent check on the zero of position-angle, and my measures of the plate indicate a zero differing by about a degree from that of Dr. Roberts. This would mean that a large part, if not the whole, of the movement assigned by him to the nebula may be due to instrumental error.

The reasons for believing that the position-angles are affected with systematic error were given in full, as was only proper in challenging the accuracy of the work of another astronomer; and I wrote to Dr. Roberts informing him of my results. He lost no time in re-examining the question, and I received from him, under date May 8, the following letter :—

"Referring to the spiral nebula M 51 *Canum*, I have obtained two photographs upon which are *star-trails* : one trail on each plate extends across the nebula. By measurements from these I find a difference of 1° 19′ in the zero of the centre of the nebula when it is compared with the zero deduced by interpolated trails, upon which I relied in the measurement of position-angles published in my second volume. Consequently the position-angles therein given on pp. 25 and 109 are 1° 19′ in excess, and this correction will have to be applied when comparisons are made with other measurements.

"I intend shortly to send to each possessor of vol. ii. a note of this and of four minor *errata* which have been found in the volume."

(Signed) "ISAAC ROBERTS."

As it is clearly preferable that a correction of this kind should be announced by the author himself, I withdraw my paper, which arrives at substantially the same result. Perhaps I may be permitted to add a word or two of cordial recognition of the way in which Dr. Roberts has throughout spared no pains to establish the truth, whatever it might be. He placed all possible information in my hands for elucidating the matter; and, when I found cause to suspect an error, lost no time in independently examining his results. His re-examination at first conducted him again to his published conclusion; but he was not content until he had checked it in yet another way by new photographs, with the result above quoted.

The Duration of the greater Sun-spot Disturbances for the years 1881–99. By the Rev. A. L. Cortie, S.J.

The number of solar drawings made at Stonyhurst during the last nineteen years amounts to 3,454, or an average of slightly over 180 each year. All the chief disturbances that have occurred during this period have been drawn at some time of their life history. In order to study the possible connection between individual magnetic storms and solar spot outbursts Father Sidgreaves has caused all the chief solar disturbances that have been recorded during these years to be charted, and their life histories to be entered in a ledger. These charts and ledger have been made use of in drawing up the present paper. The charts bear each a rotation number in continuation of Carrington's numbers, and cover the rotations from 364 to 618. Only the larger spot groups, whether single or composite in character, have been selected for entry—such as reached an area of $\frac{1}{1000}$ of the visible solar hemisphere during any part of their life history. A few other groups have been admitted, on account of their being either recurrences of these greater disturbances, or in some way connected with them. The number of such disturbances that have appeared during the 255 solar rotations under discussion amounts to 115. The present paper deals chiefly with the duration of these greater solar disturbances.

In the following table the first column gives the year, and the second the number of the groups according to the Stonyhurst charts. Those numbers which bear an asterisk denote groups that were both born and died in the visible solar hemisphere. Groups which are bracketed are obviously connected as recurrences of the same disturbance. The third and fourth columns

give to the nearest degree the mean heliographic longitude and latitude of a point which was judged by an inspection of the charts to be the centre of the group or groups covering the disturbed area. In compiling these columns our indebtedness to the Greenwich volumes giving the positions of the various groups is very great. The fifth and sixth columns give the dates of the first and last appearance of the disturbance; the seventh column shows the number of times it passed the central meridian of the visible hemisphere, and the eighth its visible duration in days; the last column states the character of the disturbance. If only one group of spots was concerned, even though it might have been of large dimensions and of great extent in area, it is entered as single. If more than one group caused the disturbance the entry is "composite." The line of distinction between these two classes of disturbance was sometimes difficult to draw when a group was very large and extended. Following the table a brief summary, with notes of some of the more obvious deductions to be drawn from an inspection of the charts, is given.

TABLE I.

Year.	Group Number.	Heliographic Long.	Heliographic Lat.	First seen.	Last seen.	Central Times.	Visible Duration, Days.	Character of Disturbance.
		°	°					
1881	1	350	−12	May 30	July 2	2	33	Single
	2	312	+24	July 25	Aug. 4	1	10	"
	3	289	+16	Oct. 14	Dec. 17	3	64	Composite
	4	226	+13	Nov. 13	23	2	40	"
1882	5	88	−18	Apr. 10	Apr. 23	1	13	Single
	6	64	−29	12	May 24	2	42	"
	7	176	+23	May 1	June 9	2	39	"
	*7a	67	+22	Sept. 2	Oct. 2	2	30	"
	8	44	−22	24	Dec. 1	3	68	Composite
	9	165	+16	Oct. 13	Nov. 20	2	38	"
	*10	121	+19	20	Dec. 20	3	61	Single
1883	11	15	+ 8	Feb. 11	Feb. 22	1	11	"
	*12	73	− 9	June 1	Aug. 19	4	79	"
	13	36	+11	25	18	3	54	"
	14	133	−22	Sept. 8	Nov. 14	3	67	"
	15	127	+11	Oct. 8	12	2	35	"
	16	36	−12	12	Jan. 13	4	93	Composite
1884	17	27	−10	Mar. 31	July 17	5	108	Single
	18	151	− 8	Apr. 21	14	4	84	"
	19	224	+16	Aug. 24	Sept. 29	2	36	"
	20	15	+15	Sept. 6	Dec. 8	4	93	Composite

Year.	Group Number.	Heliographic Long.	Heliographic Lat.	First seen.	Last seen.	Central Times.	Visible Duration, Days.	Character of Disturbance.
1884	21	55°	+8°	Dec. 20	Jan. 1	1	12	Single
1885	22	250	−14	Jan. 30	June 25	6	146	Composite
	23	123	+12	Apr. 3	8	3	66	Single
	24	250	+11	May 18	Aug. 19	4	93	,,
	25	54	−17	June 1	7	3	67	Composite
	26	355	−5	6	July 15	2	39	Single
	27	168	−13	23	Aug. 25	3	63	Composite
1886	28	34	−6	Jan. 8	May 31	6	143	,,
	29	71	−10	Mar. 29	Sept. 15	7	170	Single
	30	333	+9	May 2	June 28	3	57	,,
	31	302	−14	June 3	Aug. 5	3	63	,,
1887	*32	92	−8	May 14	Sept. 4	5	113	Composite
	*33	87	−5	Oct. 2	Oct. 4	1	2	Single
	34	83	−8	Dec. 14	Jan. 21	1	38	,,
1888	35	274	−8	May 11	May 23	1	12	,,
	*36	270	−8	July 6	July 17	1	11	,,
	37	275	−8	Aug. 8	Aug. 10	1	2	,,
	38	277	−6	28	Sept. 9	1	12	,,
	39	165	−14	Sept. 6	Dec. 9	3	94	Composite
1889	40	35	−7	June 16	Aug. 20	3	65	Single
	*41	82	−8	July 14	Sept. 4	3	52	,,
	*42	156	−22	Aug. 2	Oct. 23	4	82	Composite
1890	43	37	+21	25	2	2	38	Single
	44	28	−23	Oct. 19	Nov. 1	1	13	,,
	*45	309	+20	Nov. 22	Dec. 28	2	36	Composite
1891	46	223	+20	July 6	18	7	165	,,
	47	263	−22	Sept. 25,'91	Mar. 5, '93	20	527	,,
	47*a*	271	−20	Nov. 14	Dec. 24	2	40	Single
1892	47*b*	261	−26	Jan. 18	Mar. 17	3	59	,,
	47*c*	266	−19	May 23	June 5	1	13	,,
	47*d*	270	−20	Jan. 24,'93	Feb. 6, '93	1	13	,,
	48	190	+25	Dec. 19, '91	Jan. 27, '92	2	39	,,
	49	32	+28	Mar. 20	Apr. 2	1	13	,,
	50	83	−14	Apr. 17	May 22	2	35	,,
	51	147	+12	June 10	Sept. 29	5	111	,,
	52	40	−31	13	July 19	2	36	,,
	53	92	+11	July 4	Oct. 5	4	93	,,
	53*a*	94	+11	Oct. 29	Nov. 1	1	3	,,

Year.	Group Number.	Heliographic Long.	Heliographic Lat.	First seen.	Last seen.	Central Times.	Visible Duration, Days.	Character of Disturbance.
1892	54	5°	+15°	Oct. 2	Oct. 12	1	10	Single
	*55	24	−26	27	Dec. 2	2	36	Composite
	56	142	−24	Nov. 13	Nov. 25	1	12	Single
	57	320	−24	Dec. 24	Jan. 5	1	12	"
1893	58	15	−13	Jan. 16	27	1	11	"
	59	108	−11	Feb. 5	Feb. 18	1	13	"
	60	267	+22	Mar. 19	Apr. 28	2	40	"
	*61	141	−11	Apr. 27	May 25	2	28	"
	62	78	−21	29	July 5	3	67	"
	63	320	−15	June 5	Aug. 11	3	67	Single
	64	291	−19	13	Sept. 9	4	88	"
	65	299	+14	Aug. 2	Nov. 2	4	92	"
	66	303	− 8	3	Oct. 5	3	63	"
	66*a*	104	−16	15	Aug. 27	1	12	Composite
	67	173	− 9	19	Nov. 12	4	85	"
	68	221	− 8	Sept. 4	Sept. 14	1	10	Single
	69	340	− 7	Oct. 18	Nov. 25	2	38	"
	70	63	− 6	Nov. 9	20	1	11	"
	71	324	− 8	16	Feb. 16	4	92	Composite
1894	72	190	−30	Feb. 15	Mar. 1	1	14	Single
	73	33	+21	Mar. 28	Apr. 8	1	11	"
	*74	152	−13	30	June 16	4	78	"
	75	356	−27	Apr. 3	May 8	2	35	"
	*76	290	+17	4	12	2	38	Composite
	*77	180	−18	May 11	Aug. 9	4	90	Single
	78	130	+ 9	June 10	6	3	57	"
	79	76	−13	14	19	3	66	Composite
	80	182	+12	July 2	Sept. 9	3	69	Single
	81	27	+ 6	Aug. 11	14	2	34	"
	82	60	−12	Sept. 5	Nov. 4	3	60	Composite
	83	77	+11	Nov. 26	Dec. 6	1	10	Single
	*84	307	−19	Dec. 10	Feb. 5	3	57	"
1895	85	168	−15	15	Dec. 26	1	11	"
	86	58	−10	Jan. 21	Apr. 22	4	91	"
	87	300	+23	Apr. 20	July 16	4	87	"
	88	24	+10	Aug. 1	Nov. 2	4	93	"
	89	23	−16	Sept. 26	30	3	65	"

Year.	Group Number.	Heliographic Long.	Heliographic Lat.	First seen.	Last seen.	Central Times.	Visible Duration, Days.	Character of Disturbance.
1895	*90	326°	+ 9°	Oct. 28	Nov. 29	2	32	Single
	91	303	−13	Dec. 21	Jan. 29	2	39	„
1896	92	227	−15	Feb. 2	Mar. 2	2	29	„
	93	258	+15	18	21	2	32	„
	94	131	+17	Mar. 25	Apr. 6	1	12	„
	95	34	+16	Apr. 2	13	1	11	„
	96	72	−10	May 26	June 4	1	9	„
	*97	296	−12	Aug. 26	Sept. 30	2	35	„
	98	66	+12	Sept. 10	Oct. 13	1	33	Composite
	99	72	−16	Nov. 3	Dec. 9	1	36	Single
1897	100	345	− 6	Jan. 3	Apr. 5	4	92	„
	101	217	+ 5	20	May 16	5	116	Composite
	102	263	−10	Apr. 28	Aug. 27	5	121	„
	103	72	− 6	Aug. 2	Oct. 7	3	66	Single
	104	32	− 9	12	Sept. 13	2	32	„
	105	206	+10	Dec. 6	Jan. 15	2	40	„
1898	106	96	− 8	Jan. 18	Mar. 18	3	59	„
	107	124	−12	Mar. 6	May 1	3	56	„
	*108	238	−12	Aug. 11	Nov. 6	4	87	„
	109	310	+14	Sept. 27	3	2	37	„
1899	110	219	− 9	Mar. 15	Apr. 12	2	28	„
	111	330	+ 5	June 24	July 5	1	11	„
	*112	181	−11	15	Aug. 2	3	48	„

Summary of the Disturbances.

The rotations of the first half of 1881, those from 364 to 371, were free from greater disturbances, the first charted (Greenwich numbers 485, 500, 503) occurring during May, June, and July. Rotations 373 and 374, covering the months of August, September, and the first half of October, were also without greater spot groups. The three next rotations—375, 376, and 377—were disturbed, and were succeeded by three others—378, 379, and 380—without any great disturbance. Another set of three—381, 382, 383 (1882 March 27·76–June 17·46)—were disturbed, and these again were succeeded by yet another triplet—384, 385, 386 of solar calm. Four more rotations, 387–390, occurred before the end of 1882, and these were all disturbed. Of the five rotations, 391–395, covering the months 1883 January to May 10, only one, 393, had any signs of greater disturbance. But after these preliminary fluctuations a period of fourteen rotations commenced with 396

(1883 May 10·86), and terminated with 411 (1884 July 20·08), which were all more or less disturbed. After a breathing space of one rotation, 412, the disturbances were resumed, covering an interval of five rotations, 413 to 417 (1884 Dec. 31·27). After the lapse of another single rotation the eight rotations 419 to 426 (1885 January 26·11–September 2·13) were all subject to greater disturbances, 424 being especially affected. The four next, 427–430, were free from outbursts (1885 December 20·23). Ten rotations, 431–440, cover the period from this date to 1886 September 18·98, and they were all disturbed. This set is answered by another of eight rotations, 441–448, in a state of quiescence, thus covering the interval to 1887 April 25·47.

The solar surface, therefore, with but two short periods of rest, each extending over one rotation only, was continuously subject to these greater disturbances during the period of time from 1883 May 10·86–1885 September 2·13. After this date the fluctuation was four calm and ten disturbed rotations until 1886 September 18·98. Then ensued a distinct lull in the disturbed state of the Sun. In this connection it may be recalled, as was pointed out in a former paper (*Monthly Notices, R.A.S.* vol. xlvii. No. 1), that bands in the spectra of sun-spots—indicating presumably a cooling in the absorbing materials constituting the spots—began to appear at the commencement of 1885, and disappeared with the almost abrupt dropping of the sun-spot curve in the autumn of 1886.

After a period of rest, rotations 441 to 448, a new series of disturbances, intermittent in character, commenced in 1887 May —rotation 449. Six rotations—449 to 454—saw the life histories of two connected disturbances, two rotations—455, 456—intervened; and the same disturbance presumably, from its latitude and longitude, broke out again, and remained for yet two more rotations—457, 458. Four rotations of rest then ensued, covering the period 1888 January–May 11, and again a set of four groups broke out in a restricted area, which were presumably due to a common cause; group 35 occupying the rotation 463, rotation 464 being calm, and groups 36, 37, and 38 occurring in rotations 465, 466, 467 (1888 August 28·15). A new group, 39, appearing in rotation 467, caused the next rotation, 468, to be disturbed; 469 was then undisturbed, and group 39 again reappears in 470. The intermittent character of the action of the presumed causes of allied disturbances, the presumption resting on the identity of mean position of the several groups of spots, is very remarkable in these disturbances during the period of minimum spot activity. The six rotations 471 (1888 December 15·33) to 476 (1889 April 30·90) were quiet, while the following six, 477 (1889 May 28·12) to 482 (1889 October 11·28), were disturbed. Then came a long calm, extending over the ten rotations 483–492 (1889 November 7·58–1890 August 7·31), which closed the spot cycle. Group 40, the region of which had been disturbed since 1888 July 6, and group 41 were the last large groups of

this cycle. It is worthy of note that all the disturbances, eleven in number, which appeared in the rotations 411 to 492, covering the period of this solar minimum, were observed in the southern hemisphere of the Sun. In rotation 482, just before the long period of calm closing the cycle, appeared group 42 in south latitude 22°, which, as far as these greater disturbances are concerned, heralded the advent of a new cycle. It did not, however, commence with any appearance of continuity until group 43 broke out in north latitude 21°. As the six rotations 471 to 476 of calm were responded to by six other rotations of disturbance in the year 1889, so now again six disturbed, 493–498 (1890 August 7·31–1891 January 18·09), are followed by six undisturbed rotations, numbered 499 to 504 (1891 January 18·09–June 30·71). These alternating equal periods of calm and unrest, noticed before in the sets of rotations in the years 1881 and 1882 before the beginning of the maximum, are at least curious if merely the result of coincidence.

The new series of disturbances which commenced in rotation 505 continued for no less than sixty-seven rotations (1891 June 30·71–1896 July 1·14). This, the second maximum which occurred during the years under discussion, was marked by considerably more disturbances than was the former maximum, the ratio being about 53 to 28. During this maximum also a region of the solar surface comprised between the limits 249° to 281° of longitude and 13° to 27° of south latitude was the seat of continuous disturbance from 1891 September 25 to 1893 March 5, and of intermittent disturbance for months afterwards. Four exceptionally large groups, which were all connected the one with the other, broke out during this time—numbered 47_a, 47_b, 47_c, 47_d in the table—with thirteen other groups of smaller dimensions. Group 47_b, indeed, was the largest group as yet recorded either at Greenwich or Stonyhurst. The duration of this disturbance reached 527 days. A full discussion of this extraordinary outburst is reserved for a future occasion. Another long-continued disturbance was No. 46, which lasted for 165 days. The region of this disturbance, 20° N. latitude, corresponding to 22° S. latitude of group 47, had showed signs of unrest since 1891 April 19. From a study of these and similar outbursts it would seem probable that the force causing the disturbance acts at first in an intermittent and relatively feeble manner, until, gathering ever-increasing strength, it is manifested by an outburst of great dimensions, to be in turn followed until quiescence by yet more intermittent outbreaks. The high latitude of the spot groups in this maximum is worthy of note.

The single groups 63, 64, 65, 66 were all close together, and seemingly were connected. They were also not very far removed from the seat of action of the giant disturbance of this maximum. The composite disturbance 71 appeared in a region which continued to be intermittently disturbed until 1895 January 12. During the last three months of 1893 and the first three of 1894,

in the period covered by rotations 534 to 540, the groups appeared in low latitudes; but in rotation 540 a large group, No. 72, broke out in S. latitude 30°, followed, with the intermission of one group, by two others, 73 and 75, also in high latitudes, thus staying the gradual descent of the groups in latitude with the advance of the cycle. Even in 1896, towards the end of the maximum, the mean latitude of the groups was fairly high, about 16°. There seem to be signs of a subsidiary spot cycle being superposed on the main cycle. Groups 84, 85, 87, 88, 89, occurring when the maximum was well advanced, were all characterised by rapid growth and decline. With regard to other groups of the period, it may be noted that 82 is a possible recurrence of 79, while 85 is a probable recurrence of 77. The connecting link between these last two disturbances is a minor outbreak in the same region in 1894 November. Subsequently, too, the same region was again disturbed, though in a less degree, in 1895 January.

After the disturbances during this long-continued period of unrest had at length subsided, but two rotations of quiet intervened, 572 and 573, when a remakable continuous stream of most irregular spots, extending at least 25° in longitude, appeared during the two following rotations, 574 and 575. No sooner had it vanished than its counterpart appeared, also during two rotations, 576, 577, S. of the equator, of almost equal length, of similar character, and in approximately the corresponding longitude and latitude. Moreover, both these streams of spots were almost exactly parallel to each other, and inclined at the same angle of about 15° to the equator. This is a remarkable, but by no means a solitary, instance of correlated and answering disturbances in the same position N. and S. of the equator. The subject needs more rigorous investigation, though even a glance through the charts indicates the existence of the phenomenon. Among such groups 83 seems to answer 82, 89 responds to 88, and 93 has its counterpart in 92.

After the disappearance of these groups the solar surface continued to be disturbed through eleven rotations, 578 to 588, followed by a period of rest during two rotations, thus bringing the record down to the end of 1897. It must be noted, however, that during these rotations there was quite a sudden fall in the latitude of the five groups, 100 to 104, covering them, the drop in latitude being accompanied by a simultaneous increase in duration. The region of group 101 continued to be disturbed until November 21 by small and short-lived groups. The great decline in the mean distance of these spots from the equator has already been called attention to by the Astronomer Royal in *Monthly Notices*, vol. lix. 1. After the outburst, No. 104, the Sun was almost spotless for two rotations, 589 and 590. The next three groups in order of numbering extended over five rotations, 591 to 596 (1897 December 1·32–1898 May 14·18). For the three next rotations, 597 to 599, extending through the months 1898

May to August, the Sun was again almost entirely devoid of spots. The group 108 appeared at first small in area in rotation 600, and together with group 109 caused this and the two following rotations to be disturbed. Rotation 604 (1898 November 20·89) was the commencement of another quiet series of rotations, which lasted until the end of 607 (1899 March 10·21). The two next rotations, 608, 609, saw the life history of group 110; rotation 610 was calm; 611 to 613 were affected by groups 111 and 112; and the remaining six rotations of the years under review, 614 to 618 (1899 August 20·61–1900 January 4·09), maintained an undisturbed appearance.

In the yearly summaries of the Greenwich results for sun-spot area and position, which are published in the *Monthly Notices*, it has been noticed that the preponderance of all the sun-spots has for several years belonged to the southern hemisphere of the Sun. The same is true for the greater disturbances tabulated in this paper. Up to the end of 1886 such outbursts were equally distributed between the two hemispheres, 16 to each; but since a minimum period set in, in the year 1887, the southern hemisphere has maintained a decided supremacy until the termination of the next minimum, the numbers being 55 in the southern against 28 in the northern hemisphere.

With regard to the duration of the several groups, assuming Carrington's value of 25·38 days as the period of a solar rotation, the 115 groups are distributed as follows:—

Between rotations.	Number of groups.	Percentage.
0 to 1	28	24·3
1 to 2	34	29·6
2 to 3	24	20·9
3 to 4	19	16·5
4 to 5	5	4·3
5 to 6	2	1·7
6 to 7	2	1·7

One abnormal disturbance of 20·7 rotations is omitted.

Hence it appears that the greater number of disturbances, nearly 30 per cent., live through a period between 1 and 2 rotations.

This conclusion is borne out if the whole number of days of disturbance be divided by the total number of disturbances. From this we get that the average life of a disturbance is 56·0 days, or a little more than two rotations. If we take those groups only which were born and also died on the Sun's visible hemisphere, numbering 19 in all, and get a mean in this manner, the result is that the average life of a solar disturbance is 52·4 days, or again slightly more than two solar rotations.

The average duration, then, of a sun-spot disturbance—for we have neglected altogether the disturbances manifested by

means of faculæ—appears to be of the period of two solar rotations.

Besides this conclusion, which was the chief object for which the above table was prepared, the following points for more detailed investigation and study are suggested by the summary review of the disturbances during the last nineteen years :—

(1) In the alternations of quiet and disturbed periods, seven of twenty-two are of equal duration reckoned in rotations of the Sun. Is this equality of alternating periods merely a coincidence?

(2) The action of the foci of disturbance differs in the maximum and in the minimum periods of sun-spots. In the former it is at some time continuous, in the latter always intermittent.

(3) In a set of allied disturbances the mode of action of the force causing them is at first intermittent, then culminates in a grand outburst, and dies away in another set of intermittent disturbances.

(4) The superposition of minor subsidiary cycles of disturbance upon the main cycle of eleven years seems to be apparent.

(5) Groups towards the end of the period of maximum seem to grow and decline very rapidly.

(6) There seems to be no doubt that allied disturbances occur in identical positions north and south of the equator of similar character and extent.

(7) The noteworthy concentration of disturbances in the southern hemisphere of the Sun during the last maximum and the preceding minimum suggests an answering concentration of disturbances in the northern hemisphere in the coming maximum.

Stonyhurst College Observatory:
1900 *May* 5.

Note on Measures by Professor Barnard of two Standard Points on the Moon's Surface. By S. A. Saunder, M.A.

In a paper communicated to the Society last January (*ante*, p. 174) attention was called to the increase of accuracy in selenographic positions which might be attained by measuring from a well-determined point instead of from the limb, and to the suitability of Mösting A as an origin. It was my good fortune that Professor Barnard was present at the meeting at which the paper was read, and the next day he most kindly offered to measure a few points on the Moon itself if the results would be of any assistance to me. This generous offer I gladly accepted, and I have now received from him the particulars of measures made on April 7 and 9, with the full aperture of the 40-inch telescope of the Yerkes Observatory, and a magnifying power of

700 diameters. The measures made were of the distances and position-angles of the lines joining the centres of Mösting A, Ptolemaus A, and Triesnecker B. Each position-angle was measured four or five times on each night, and each distance eight or nine times. These measures I have reduced by the methods described in the paper referred to with the following results.

Assuming Professor Franz's position for Mösting A and denoting the coordinates of the other points by the suffixes p, t respectively, Professor Barnard's measures give :—

1900 Apr. 7	$\xi_p = -\cdot 0142$	$\eta_p = -\cdot 1478$
	$\xi_t = +\cdot 0071$	$\eta_t = +\cdot 0202$
	$\xi_t - \xi_p = +\cdot 0212$	$\eta_t - \eta_p = +\cdot 1686$
Apr. 9	$\xi_p = -\cdot 0141$	$\eta_p = -\cdot 1477$
	$\xi_t = +\cdot 0072$	$\eta_t = +\cdot 0207$
	$\xi_t - \xi_p = +\cdot 0217$	$\eta_t - \eta_p = +\cdot 1684$

the absolute values of the coordinates being obtained from the measures connecting the points with Mösting A, those of the differences from measures connecting the points directly. The final values obtained from these are :—

$$\xi_p = -\cdot 0142 \pm \cdot 00007 \qquad \eta_p = -\cdot 1479 \pm \cdot 00007$$
$$\xi_t = +\cdot 0072 \pm \cdot 00007 \qquad \eta_t = +\cdot 0205 \pm \cdot 00007$$

Professor Barnard writes : "The measures were made with the utmost care that could be exercised under the conditions," but "the objects are so large, especially with a big telescope, that considerable discordances might be expected in the measures from difference of illumination, position, &c."

"On April 7 the three craters were approximately measured. The seeing was very poor (on the 9th also), and the crater form was not well enough seen to make exact measures, but these will not be far out. They will give some idea of the size of the spot one has to bisect in making the measures.

Apparent diameter of	Mösting A	6″·38
„ „	Ptolemaus A	4·66
„ „	Triesnecker B	2·94 "

The position-angles of the measured diameters were such that these distances require to be multiplied by 1·0270, 1·0262, 1·0058 respectively in order to obtain the corresponding maximum diameters. The Moon's occultation radius at the time was 908″·0, and hence, remembering that the formations were nearer

than the radius which subtends this angle, the real diameters are found to be :—

Mösting A	·00718 of Moon's radius	=7·77 miles
Ptolemaus A	·00524 „ „	=5·67 „
Triesnecker B	·00325 „ „	=3·51 „

One of my reasons for asking for measures of these particular points was that, their positions being known, I should be able to find the centre of the disc on any given photograph on which they appear without encountering the difficulties involved in measuring from the limb. A second reason was that a comparison of my own results with Professor Barnard's would show whether my measures are affected by any serious systematic error.

In my previous paper (*ante*, p. 181) I give the results of five nights' measures of Ptolemaus A, of which the means are :—

$$\xi_p = -·0139 \qquad \eta_p = -·1477$$

I have also taken the following :—

1900 Feb. 8	$\xi_p = -·0139$	$\eta_p = -·1472$
1899 Nov. 18	$\xi_t = +·0068$	$\eta_t = +·0205$
Dec. 13	$+·0076$	$+·0203$
15	$+·0079$	$+·0206$
1900 Feb. 8	$+·0073$	$+·0204$
8	$\xi_t - \xi_p = +·0210$	$\eta_t - \eta_p = +·1687$
9	$+·0213$	$+·1685$

The final result from all my measures being

$$\xi_p = -·0139 \pm ·00008 \qquad \eta_p = -·1478 \pm ·00008$$
$$\xi_t = +·0073 \pm ·00009 \qquad \eta_t = +·0206 \pm ·00010$$

My individual measures are, as was to be expected, more discordant than those of Professor Barnard, but on comparing my final values with his it appears that in only one case is there a difference of more than ·0001, *i.e.* of more than 0″·1, and this coordinate, for which the difference is 0″·3, is the one in which the two causes noticed by Professor Barnard, viz. size of objects measured and changes of illumination, combine to produce their greatest effect.

In order to test the existence of systematic error more closely, I have, from these places, computed the values of the lines and angles actually measured as they would appear under mean libration. The following are the results from Professor Barnard's measures :—

Lengths of Lines.

MP ·1194 , MT ·1234 , PT ·1698

Inclinations to Axis of ξ.

MP 129°·39 , MT 38°·06 , PT 82°·76

From my measures:—

Lengths of Lines.

MP ·1195 , MT ·1236 , PT ·1697

Inclinations to Axis of ξ.

MP 129°·54 , MT 38°·07 , PT 82°·82

This comparison seems to justify the conclusion that my measures are subject to no serious systematic error, and to support my claim that the positions given in my previous paper are of a higher order of accuracy than those found by measuring from the limb.

These two points, Ptolemaus A and Triesnecker B, are now—next to Mösting A—the best known positions on the Moon's surface.

Professor Barnard says in the letter which accompanies his measures that he had intended to give three nights to the work, but that he found it too trying to his eyesight. The fact that under these conditions he did not stop after the first night renders the extent of my obligation to him a very great one; and I am sure that all will concur in the earnest hope that what he has so kindly done may not have impaired that well-known sensitiveness of retina of which his discoveries have given so many proofs.

On Planning Photographic Observations of Eros. Arthur R. Hinks, M.A.

1. In considering a scheme of photographic operations for the coming opposition of *Eros* the following points suggest themselves:—The planet is so faint, and its motion is so rapid, that it will be necessary with all instruments, except perhaps the largest, to follow on the planet and let the stars trail. In September and October, and again in January, the necessary exposures will run into minutes, especially since, according to Professor Pickering, the planet is photographically about $0^{m}\cdot6$ fainter than the visual magnitude.

Even at its brightest the planet will be a difficult object to follow visually in the guiding telescope; and when it is fainter it will probably be impossible to guide upon it. Moreover, in some modern instruments the guiding telescope is dispensed with, and a star just off the edge of the plate is kept bisected in a guiding eyepiece. In such a case it is, of course, impossible to guide directly on the planet, and it will be necessary to give the plate a continuous movement whose direction and velocity are calculated beforehand.

It looks, then, as if it will be necessary in most cases to substitute guiding by calculated displacements for visual following. To meet such a contingency the screws which move the plate-holder of the Cambridge Equatorial along rectangular slides on the breech-piece of the telescope have been provided with divided heads. It would be possible to get the requisite motion of the plate by turning the heads through calculated small amounts at successive intervals of a few seconds. But to work the two slides simultaneously in this way would be too complicated. It seems to me that the better plan will be to get the trail in R.A. by adding weights to or removing them from the dish of the pendulum which controls the driving clock, after the plan described by Dr. Rambaut ("On the Inequality in the Apparent Movement of Stars due to Refraction, and a Method of allowing for it in Astronomical Photography," *Monthly Notices*, 1896, vol. lvii. p. 50). The observer will then be free to concentrate his attention on giving the motion to the declination slide.

2. In calculating the rates of displacement required we must take account of—

a. The proper motion of the planet.

b. The variation of the refraction with the hour-angle.

c. The variation of the parallactic displacement with the hour-angle.

d. The effect of any error in the adjustment of the instrumental to the true pole.

2*a*. The proper motion of the planet is given in the ephemeris by Dr. Millosevich in the *Berliner Jahrbuch* for 1902. The losing rate to be given to the clock is equal to the rate of increase of the planet's R.A.

2*b*. Let ϕ be the astronomical latitude,
δ the declination of the planet,
h its hour-angle measured west,

and let $\tan\theta = \cot\phi\cos h$.

It is easily shown that the trail in R.A. is equivalent to a losing rate of the clock of

$$24^{s}\cdot5\,\frac{\sin\theta\cos\theta}{\sin^2(\delta+\theta)}\,(\tan\delta+\cot\phi\sec h)\text{ per day.}$$

The rate of trail in declination is equivalent to a motion of

$$+15''\cdot3\cot\phi\sin h\operatorname{cosec}^2\overline{\delta+\theta}\cos^2\theta\text{ per hour.}$$

(For proof of the latter result see a paper by the writer in *Monthly Notices*, 1898, vol. lviii. p. 430.)

2c. Let ϕ_0 be the geocentric latitude,
Δ the distance of the planet from the Earth.

The rate of trail in R.A. is equivalent to a gaining rate of

$$3^s\cdot69 \times 1/\Delta \times \cos\phi \cos\phi_0 \sec\delta \cos h \text{ per day,}$$

and the rate of increase of declination is

$$-2''\cdot3 \times 1/\Delta \times \cos\phi_0 \cos\phi \sin\delta \sin h \text{ per hour.}$$

2d. It has been shown by the writer (*loc. cit.* pp. 429, 433) that if the instrumental is displaced from the true pole by 100″ in hour-angle H, the correction required in R.A. is equivalent to a gaining rate of the clock of

$$41^s\cdot9 \cos(h - \mathrm{H}) \tan\delta \text{ per day,}$$

and the apparent rate of increase of declination is

$$-26''\cdot2 \sin(h - \mathrm{H}) \text{ per hour.}$$

The rates for other displacements are proportional.

3. Take as an example the case of photographing the planet at Cambridge on September 17, 21^h W. of the meridian.

	Clock rate.	Decl. rate.
	s	″
Proper motion	−45·0	+57·1
Refraction	−22·2	− 7·5
Parallax	+ 1·8	+ 0·6
Error of pole (say 50″ in 13^h west)	−17·0	−11·4
	−82·4 per day.	+38·8 per hour.

The photographic magnitude on this day will be about $12\frac{1}{2}^m$. Suppose that it requires 10^m exposure. The displacement due to other causes than proper motion amounts to about $4\frac{1}{4}''$ during that time; and unless they are taken into account the planet will not be photographed, even if its proper motion of 1″ per minute is allowed for.

4. It is clear that to deal with *Eros* successfully requires that the instrumental adjustment shall be of great accuracy. In the case of our example, if we can rate our control pendulum perfectly, we shall have to deal with a rate in declination of 0″·65 per minute. With a half-millimetre screw and head divided into 100 parts, we shall be able to follow by turning the head three-tenths of a division every five seconds.

With the standard astrographic equatorial it would be impossible to guide visually upon a planet of magnitude $12\frac{1}{2}$. It seems that it might be well to provide such an instrument with

a slide and screw motion of the plate-holder in declination such as I have described.

The accompanying plate (Plate 17) has been drawn to help in planning the night's work. It shows for Cambridge (lat. 52° 13') the zenith distance of the planet for every hour of the night at intervals of fourteen days, with the corresponding parallax factor; the computed photometric magnitudes, according to Pickering; the proper motion of the planet (on the scale side of one square=2" per minute), and the limits to the observations imposed by daylight.

Cambridge Observatory:
1900 *May* 9.

Observations of the Spots and Markings on the Planet Jupiter, made at the Dearborn Observatory of North-Western University, Evanston, U.S.A. By G. W. Hough, Director.

(*Communicated by the Secretaries.*)

The spots and markings on the surface of the planet *Jupiter*, dealt with in the present paper, have been located by means of the micrometer, and, with a few exceptions, a magnifying power of 400 has been used. If a lower power, viz. 190, is employed, the finer details cannot be well seen.

Hitherto observers have confined their observations almost entirely to displacement in longitude or rotation period. I believe that displacements in both longitude and latitude are essential for the correct interpretation of the phenomena seen on the surface.

The position of a spot or marking is determined when it is wholly on the disc, but preferably near the central meridian.

An observation for position usually consists of three measures from each limb of the planet. The measures are referred to both limbs in order to eliminate the error due to irradiation, or, what is of great importance, the enlargement of the disc due to imperfect definition.

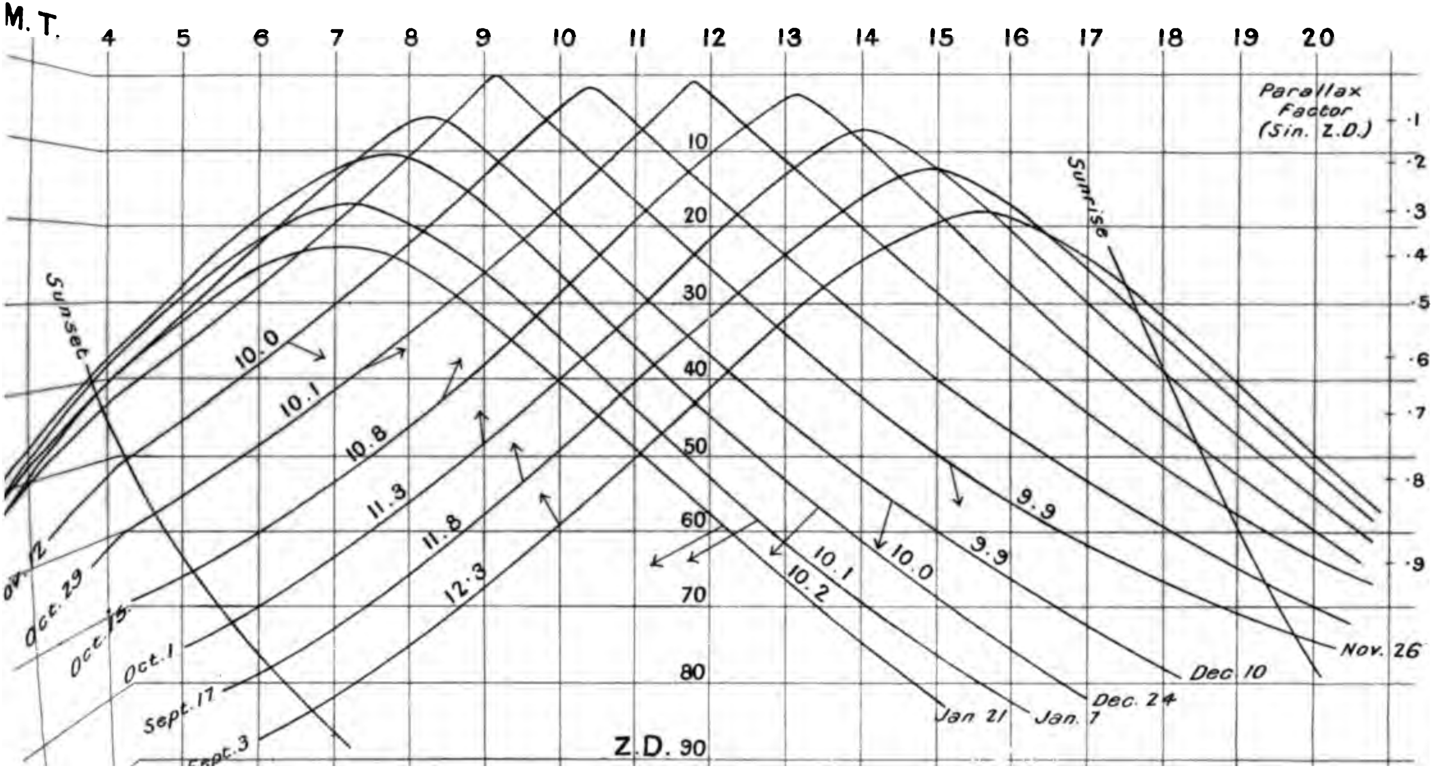
T=time of passage over the central meridian of the luminous disc, not corrected for defective illumination. The time is that of the 90th meridian, or 6 hours slow of Greenwich M.T.

β=distance from the apparent equator of the disc. After applying the correction for the elevation of the Earth above *Jupiter's* equator, the distance north or south of the equator is designated reduced latitude.

L=length of chord on middle of disc.

In the determination of rotation period the observations have been corrected for longitude of equinox, aberration time, annual parallax, and defective illumination. With the exception of the

OPPOSITION OF EROS 1900.



longitude of equinox, all the other corrections have been derived from Marth-Crommelin ephemerides.

All measures are reduced to mean distance.

The Great Red Spot.

The great Red Spot remained faint and indistinct for the greater portion of the time covered by these observations. Near the time of opposition, however, the outline could be traced, and the spot appeared of a greenish tint. In the absence of the depression in the equatorial belt, the spot long ago would have escaped notice in most telescopes.

The rotation period for the great Red Spot is still slowly increasing.

Date.		Rotation. h m	s
1896		9 55	41·42
1897		"	41·32
1898		"	41·62
1899		"	41·76
Interval.	**Days.**		
5600	6000	"	41·38
6000	6400	"	41·32
6400	6800	"	41·54
6800	7200	"	41·68

The rotation periods for the 400-day intervals were computed by using normal places for each opposition.

The probable error on the rotation period for the 400-day interval is $\pm 0^{\cdot}04$ sec., but owing to the faintness of the object during recent years, there may be considerable systematic error in locating the centre of the spot.

The 400-day intervals are counted from 1879 September 25.

The observations for each opposition, usually, could be better satisfied by making the rotation period a function of the time; but during recent years the spot has been so faint that observations of a high degree of precision were impossible. The residuals in the column O—E show, however, that at no time has there been any abrupt change in the rate of motion of the spot.

The great Red Spot is not stationary in latitude.

Its mean position 1879 to 1899 is:

Reduced Latitude $-6''{\cdot}27 = 18^{\circ}{\cdot}9$ Jovicentric Latitude.

The results for the last four years are as follows:

Year.	Mean Day.	Reduced Latitude.	
		$''$	
1896	6019	−5·64	17 obs.
1897	6395	−6·07	14 "
1898	6786	−6·14	15 "
1899	7126	−6·23	4 "

The greatest and least mean values for the latitude during any opposition since 1879 are as follows:

Year.	Mean Day.	Reduced Latitude.	
1886	2385	$-7''.21$	9 obs.
1893	5194	-5.53	8 „

These numbers indicate that the spot has drifted in latitude about 4,000 miles.

Owing to the faintness of the spot during the past four years, the measures of length are few, and should be regarded as approximate.

The mean of six nights 1897–98 is $11''.46$. During the earlier years, when the outline of the spot was well defined, the adopted value for the length was $11''.61$ or $37^\circ.2$. It seems probable, therefore, that the spot has not materially changed in size during the past twenty years.

The following table gives the observations in detail, and the comparison with an Ephemeris. As might be expected, the residuals, Obs.-Eph. are somewhat greater than when the spot was well defined.

The Great Red Spot. $R=9^h\ 55^m\ 41^s.42$.

Date.	Days.	T	O−E.	β
1895.		h m	m	''
Nov. 2	0	18 21·4	−0·8	...
Dec. 15	43	8 53·0	−1·2	−5·95
31	59	12 01·4	−1·6	...
1896.				
Jan. 29	88	10 55·6	+0·7	...
Feb. 5	95	11 39·8	−0·4	5·81
8	98	9 11·2	+1·4	5·46
13	103	8 14·9	−2·4	5·96
27	117	9 49·0	−0·6	...
28	118	5 39·2	−1·6	6·38
Mar. 1	120	7 20·9	+1·6	5·80
3	122	8 57·6	+0·8	5·73
8	127	8 05·6	−0·4	5·59
20	139	7 58·4	−3·6	5·88
23	142	5 31·5	−0·6	6·34
27	146	8 50·7	+1·1	...
Apr. 1	151	8 00·7	+1·9	5·67
3	153	9 39·5	+1·8	5·73
6	156	7 12·7	+4·6	5·53
27	177	9 34·4	+0·9	...
30	180	7 06·7	+2·5	5·70
May 2	182	8 40·6	−2·7	5·84
26	206	8 37·7	−3·7	5·15
June 5	216	7 02·0	−1·9	6·04

The Great Red Spot. $R = 9^h\ 55^m\ 41^s.32$.

Date 1897.	Days.	T. h m	O−R. m	β ″	L. ″
Jan. 18	0	10 15 est.	−2·0	...	...
20	2	11 56·2	+1·4	+6·33	11·92
30	12	10 10·2	+0·8	5·65	...
Feb. 13	26	11 38·4	−0·8	5·34	...
18	31	10 44·9	−1·4	6·10	...
Mar. 3	44	6 34·2	−0·2	5·54	...
9	50	11 27·1	+2·1	...	...
10	51	7 20·2	+3·8	5·73	...
12	53	8 57·5	+2·8	5·93	...
15	56	6 25·1	+1·1	5·60	...
Apr. 17	89	8 33·4	−4·8	5·43	...
24	96	9 24·8	−0·5	5·88	10·31
May 18	120	9 19·9	−0·4	5·07	...
28	130	7 35·3	−4·0	...	...
June 21	154	7 40·0	+3·3	5·93	...

The Great Red Spot. $R = 9^h\ 55^m\ 41^s.62$.

Date. 1897.	Days.	T. h m	O−R. m	β. ″	L. ″
Dec. 6	0	17 14·7	+0·0	...	...
1898. Jan. 2	27	14 37·5	+2·2	...	...
13	38	18 39·9	+0·7	−5·05	...
Mar. 4	88	9 55·9	+1·5	5·67	...
23	107	10 36·6	+4·5	5·46	...
28	112	9 39·8	+0·5	5·27	...
Apr. 2	117	8 46·6	−0·2	4·79	...
5	120	6 15·1	−1·0	...	...
7	122	7 55·4	−1·1	5·59	...
9	124	9 31·0	−1·5	5·90	10·30
16	131	10 18·7	+0·5	...	...
28	143	10 10·0	−2·4	4·71	11·31
May 3	148	9 16·5	−4·0	5·80	11·79
8	153	8 24·6	−4·2	5·29	12·45
June 1	177	8 23·0	+1·7	5·01	...
3	179	10 00·2	+0·1	5·49	...
8	184	9 11·9	+2·6	4·57	...
13	189	8 16·8	−1·7	5·20	...
25	201	8 12·9	−3·8	...	...
27	203	9 57·6	+2·0	6·15	...
July 7	213	8 15·6	+0·8	...	...
12	218	7 23·8	−0·8	...	...
14	220	9 01·4	−2·1	...	...

The Great Red Spot. R = 9h 55m 41s·76.

Date. 1898.	Days.	T. h m	O–E. m	β ″
Dec. 10	0	18 02·5	+3·6	...
1899. Jan. 15	36	17 47·7	–0·8	...
Feb. 28	80	14 09·1	–1·5	–5·84
Mar. 19	99	14 50·2	+0·2	5·03
Apr. 8	119	11 18·6	–0·2	5·03
23	134	8 41·1	+0·5	...
25	136	10 18·7	–0·2	...
May 2	143	11 02·7	–1·3	4·68
9	150	11 44·7	–1·6	...
22	163	7 36·7	+2·0	...
26	167	10 54·0	+2·8	...
27	168	6 41·6	–0·9	...
29	170	8 19·6	–1·3	...
31	172	9 59·0	–0·5	...
June 3	175	7 31·1	+1·8	...
5	177	9 08·5	+0·7	...
7	179	10 45·5	+0·2	...
9	181	12 29·8	+5·1	...
12	184	9 56·2	+1·4	...
19	191	10 41·6	–0·2	...
24	196	9 51·1	+0·3	...
29	201	8 57·6	–2·2	...
July 1	203	10 36·3	–2·4	...
6	208	9 42·0	–5·8	...
11	213	8 56·1	–0·9	...
28	230	8 03·8	–0·7	...
Aug. 9	242	8 06·2	+3·3	...

Black and White Spots.

The following table gives the date; longitude at the time of the first observation from Marth-Crommelin Meridian II.; interval in days between the first and last observation; the reduced latitude and the rotation period:—

Date.	Long. h m	Days.	Red. Lat. ″	Rotation P. h m s
1895 Oct. 29	+2 17	156	+8·39	9 55 60·48
1897 Apr. 9	+8 10	46	+8·18	59·7
1898 Mar. 13	+7 15	58	+8·05	52·1
1895 Oct. 18	+6 19	179	+4·45	31·8

Date.			Long. h m	Days.	Red. Lat. "	Rotation P. h m s
1895	Oct.	18	+7 52	199	+4·66	9 55 34·2
1897	Dec.	26	+0 24	191	+4·34	27·2
1898	Mar.	1	+8 54	132	+4·36	26·6
1898	Apr.	1	+7 17	74	+4·41	26·6
1899	Mar.	28	+5 26	63	+5·01	20·8
1899	Apr.	3	+9 24	96	+4·89	32·3
1899	May	26	+0 03	29	+4·9	34·2
1897	Feb.	17	+4 07	31	+4·17	47·6
1899	May	27	+1 52	7	+3·83	20·7
1897	Jan.	9	+4 29	104	+3·11	48·6
1897	Jan.	18	+2 19	140	+1·49	47·9
1897	Feb.	20	+6 10	62	+2·29	09·1
1897	Feb.	27	+5 19	100	+1·48	09·2

Meridian I.

1899	Apr.	4	+6 20	80	−2·56	9 50 29·9
1899	May	9	+6 58	34	−1·41	23·9

An inspection of the above table shows a variation of fifty-one seconds in the length of the rotation period $9^h\ 55^m +$.

The spots observed in reduced latitude $+8''$, during the three successive oppositions 1895 to 1898, give the longest rotation periods I have observed, covering a long interval of time. An acceleration in the rotation period at this latitude is clearly shown during the three years. Some of the spots observed in 1897 bring the rotation period $9^h\ 55^m +$ within five degrees of the equator.

The observations which follow indicate the kind of spot observed, latitude, length, and comparison with an Ephemeris.

Black Spots B_2. $R = 9^h\ 56^m\ 00^s{\cdot}48$.

Date.	Days.	T h m	O−E. m	β "	L. "
1895. Oct. 29	0	17 08·7	+1·0	+7·87	...
1896. Feb. 21	115	[8 19·1]	−5·9	...	...
Mar. 2	125	6 46·9	−2·0	...	...
4	127	8 28·7	+0·0	+8·45	4·23
16	139	8 33·6	−0·1	+8·29	3·48
23	146	9 27·2	+1·0	...	...
April 2	156	7 50·5	−1·9	...	...

Mean reduced lat. $+8''{\cdot}39$. 3 obs.

Length ... ... $3''{\cdot}85$. 2 obs.

$R = 9^h\ 55^m\ 59^s \cdot 7$.

Date. 1897.	Days.	T. h m	O–E. m	β ″	L. ″
April 9	0	9 45·4	−4·6	+8·40	6·90
14	5	9 01·8	−0·6	8·44	...
17	8	6 35·1	+0·5	8·51	6·51
19	10	8 15·8	+1·0	...	...
24	15	7 32·7	+5·4	8·69	6·40
26	17	9 05·6	−1·9	...	...
May 13	34	8 24·7	−2·0	8·27	...
15	36	10 09·8	+2·9	8·64	...
25	46	8 32·6	−0·6	...	...

Mean reduced lat. +8″·18. 6 obs.

Length ... ... 6″·60. 3 obs.

$R = 9^h\ 55^m\ 52^s \cdot 1$.

Date. 1898.	Days.	T. h m	O–E. m	β ″	L. ″
Mar. 13	0	8 55·9	+0·0	+9·48	5·03
30	17	8 03·4	+0·5	+8·50	...
April 1	19	9 40·5	−1·4	8·90	5·41
6	24	8 50·3	−1·2	8·36	5·22
11	29	8 00·2	−0·9	8·65	4·82
May 7	55	9 40·2	+1·1	8·81	...
10	58	7 10·5	+0·1	8·94	...

Mean reduced lat. +8″·05. 7 obs.

Length ... ... 5″·12. 4 obs.

Black Spot a. $R = 9^h\ 55^m\ 31^s \cdot 8$.

Date. 1895.	Days.	T. h m	O–E. m	β ″
Oct. 18	0	17 07·0	+2·6	...
Nov. 4	17	16 00·9	−0·7	+4·13
Dec. 9	52	9 44·5	+1·6	+4·50
21	64	9 33·0	+2·0	+4·11
26	69	8 37·6	+0·7	...
30	73	11 50·0	−0·9	+3·97
1896. Jan. 9	83	9 58·5	−3·0	+4·06
11	85	11 36·4	−2·3	...
14	88	9 04·7	−1·6	...
29	103	6 25·4	+3·2	+4·73
Feb. 5	110	7 06·5	+1·3	+4·72
10	115	6 11·0	+0·2	...

Date.	Days.	T.	O—R.	β
1896.		h m	m	"
Mar. 16	150	9 42·6	−7·2	+4·14
19	153	7 19·2	+0·2	...
April 2	167	8 45·1	−3·9	...
14	179	8 43·7	+1·9	...

Mean reduced lat. +4″·45. 8 obs.

Length ... ... 2″·19. 3 obs.

Black Spot b. R = 9ʰ 55ᵐ 34ˢ·2.

Date.	Days.	T.	O—R.	β
1895.		h m	m	"
Oct. 18	0	18 40·3	−0·5	...
Nov. 4	17	17 36·6	−2·9	...
Dec. 9	52	11 28·5	+4·2	...
21	64	11 14·6	+1·0	...
26	69	10 23·4	+4·0	...
31	74	9 31·2	+5·9	...
1896.				
Jan. 2	76	11 05·5	+2·5	...
10	84	7 44·9	+8·3	...
14	88	10 45·4	+5·9	...
20	94	5 51·6	+3·3	+4·61
29	103	8 10·7	+1·8	...
Feb. 5	110	8 53·4	+1·1	...
8	113	6 22·5	+1·6	+4·07
10	115	8 00·1	+1·6	...
27	132	7 02·4	+5·0	+4·27
Mar. 19	153	9 05·0	−7·1	+4·30
April 2	167	10 35·3	−8·4	+4·41
15	180	6 28·8	−0·2	+4·84
22	187	7 10·9	−4·7	+4·69
27	192	6 19·2	−2·5	+5·05
29	194	7 54·9	−5·3	+4·18
May 4	199	7 06·5	−2·0	...

Mean reduced lat. +4″·66. 9 obs.

Length ... ... 1″·88. 2 obs.

The spot was nearly round, and appeared like the shadow of a satellite.

Black Spot a. R = 9^h 55^m 27^s·2.

Date. 1897.	Days.	T. h m	O–E. m	β ″	L. ″
Dec. 26	0	[17 35] est.	+0·3	...	...
1898. Feb. 13	49	12 37·7	+3·6	+4·24	...
Mar. 7	71	10 26·2	−2·5	4·89	5·59
17	81	8 38·3	+1·0	5·01	6·06
24	88	9 17·5	−1·0	5·48	7·16
29	93	8 21·6	−2·3	5·16	6·78
31	95	9 57·3	−3·5	5·77	6·13
April 5	100	9 01·4	−5·1	5·23	7·17
7	102	10 41·6	−1·7	...	8·45
10	105	8 07·1	−3·7	...	...
15	110	7 16·7	+1·0	5·52	...
24	119	9 30·7	−1·9	...	...
29	124	8 37·2	−0·8	5·26	8·00
May 13	138	10 04·8	+1·3	...	...
23	148	8 18·3	+3·1	5·05	7·30
30	155	9 00·8	+1·9	4·42	6·96
June 4	160	8 08·0	+2·9	5·26	7·94
28	184	[7 54·9]	(+8·3)	5·15	...
July 5	191	8 29·2	−2·3	5·79	...

Mean reduced lat. +4″·34. 14 obs.
Length ... ... 7″·05. 11 obs.

Black Spot b. R = 9^h 55^m 26^s·6.

Date. 1898.	Days.	T. h m	O–E. m	β ″	L. ″
Mar. 1	0	[10 43] est	[+9·1]	...	...
13	12	10 18·3	−1·1	+4·85	3·45
23	22	8 32·4	+4·5	5·38	4·23
30	29	9 06·9	−2·2	5·63	5·60
Apr. 1	31	10 48·1	+2·2	5·25	5·80
11	41	8 52·2	+2·2	5·41	6·50
16	46	7 55·8	+0·2	...	...
28	58	7 42·5	−2·0	...	...
May 3	63	6 48·8	−2·9	...	...
5	65	8 26·1	−2·8	...	...
7	67	10 01·6	−4·7	...	...
10	70	7 36·5	+2·1	5·18	...
12	72	9 12·8	+1·3	...	...
17	77	8 15·1	−2·1	...	...
June 17	108	8 39·8	−0·6	...	...
July 6	127	9 13·9	−2·0	...	...
11	132	8 21·5	−1·3	4·75	...

Mean reduced lat. +4″·36. 7 obs.
Length ... ... 5″·12. 5 obs.

Black Spot. $R = 9^h\ 55^m\ 48^s{\cdot}6.$

Date.	Days.	T.	O—R.	β
1897.		h m	m	″
Jan. 9	0	11 56·3	+0·0	+3·4 est.
Feb. 24	46	10 00·3	−1·2	+3·54
Mar. 20	70	9 54·9	+0·0	...
Apr. 23	104	8 13·0	+1·2	...

Reduced lat. $+3''{\cdot}11.$

Black Spot. $R = 9^h\ 55^m\ 47^s{\cdot}6.$

1897.		h m	m	″
Feb. 17	0	8 40 est.	+0·0	...
27	10	6 55·2	−2·3	+4·60
Mar. 20	31	9 19·9	+0·0	...

Reduced lat. $+4''{\cdot}17.$

White Spot. $R = 9^h\ 50^m\ 29^s{\cdot}9.$

1899.		h m	m	″
Apr. 4	0	11 24·1	+0·0	−0·93
May 11	37	9 04·5	+3·3	...
June 21	78	9 10·0	+0·8	−1·74
23	80	10 22·0	+0·1	−1·61

Mean reduced lat. $-2''{\cdot}56.$ 3 obs.

White Spot. $R = 9^h\ 50^m\ 23^s{\cdot}9.$

1899.		h m	m	″
May 9	0	8 28·2	+3·2	−0·23
11	2	9 32·0	−3·8	−0·38
June 12	34	8 52·3	+0·0	−0·41

Mean reduced lat. $-1''{\cdot}41.$ 3 obs.

Black Spot. $R = 9^h\ 55^m\ 09^s{\cdot}2.$

1897.		h m	m	″
Feb. 27	0	8 06·2	+1·0	...
Mar. 20	21	9 54·9	−0·1	...
Apr. 25	57	8 53·1	−0·8	+1·78
May 4	66	11 09·5	+0·6	+1·86

Reduced lat. $+1''{\cdot}48.$ 2 obs.

Black Spot. R = 9^h 55^m $09^s.1$.

Date. 1897.	Days.	T. h m	O—E. m	β ″
Feb. 20	0	8 12·1	+2·1	...
22	2	9 44·1	−1·6	...
27	7	8 45·9	−0·3	...
Apr. 23	62	8 13·0	−0·1	+2·62

Reduced lat. +2″·29.

Black Spot. R = 9^h 55^m $47^s.9$.

1897.				
Jan. 18	0	12 10·0	+0·0	...
Feb. 15	15	9 34·0	−1·6	...
24	37	7 52·4	+4·4	...
Apr. 25	97	7 28·5	−7·3	+1·78
May 4	106	10 06·2	+1·4	+1·86
June 7	140	8 28·7	+0·6	...

Reduced lat. +1″·48. 2 obs.

Black Spot .C. R = 9^h 55^m $26^s.6$.

Date. 1898.	Days.	T. h m	O—E. m	β ″	L. ″
Apr. 1	0	9 35·5	+2·0	...	...
6	5	8 37·6	−0·4	...	...
11	10	7 41·5	−1·0	+5·41	2·81
20	19	9 57·3	−3·8	...	...
May 7	36	8 54·0	+0·3	5·04	2·50
12	41	7 59·8	+0·7	...	...
June 14	74	10 01·4	+2·1	...	...

Mean reduced lat. +4″·41. 2 obs.
Length ... ... 2″·65. 2 obs.

Long Black Spot. R = 9^h 55^m $20^s.8$.

1899.					
Mar. 28	0	11 47·3	+0·0	...	2·5 est.
May 1	34	9 25·3	+6·8	...	7·91
8	41	9 51·1	−7·0	+6·03	2·54
10	43	11 27·2	−6·4	...	2·5 est.
30	63	7 49·2	+0·0	...	7·33

Reduced lat. +5″·01.

White Spot. $R = 9^h\ 55^m\ 20^s.7$.

Date. 1899.	Days.	T. h m	O—R. s	β ″
May 27	0	7 35·6	+0·0	+4·85
29	2	9 12·9	+0·6	...
June 3	7	8 16·4	+0·0	...

Reduced lat. + 3″·83.

White Spot. $R = 9^h\ 55^m\ 32^s.3$.

1899.				
Apr. 3	0	10 43·0	+3·2	+5·76
8	5	9 43·6	−1·6	...
25	22	8 38·0	−0·6	+6·22
May 4	31	10 55·7	−3·1	...
26	53	8 59·1	−0·4	...
31	58	8 04·6	−1·2	...
June 7	65	8 48·8	−1·0	...
9	67	10 29·6	+1·8	...
12	70	7 57·0	+0·7	+6·26
19	77	8 43·0	+2·2	...
24	82	7 51·7	+3·9	...
26	84	9 22·4	−3·5	+5·41
July 1	89	8 34·2	+1·1	...
8	96	9 16·7	−1·8	+5·90

Mean reduced lat. + 4″·89. 5 obs.

White Spot. $R = 9^h\ 55^m\ 34^s.2$.

1899.				
May 26	0	9 55·5	+0·0	...
31	5	9 04·2	+2·0	...
June 7	12	9 41·6	−5·2	...
9	14	11 19·8	−4·9	...
12	17	8 51·8	−2·0	...
19	24	9 42·3	+3·4	...
24	29	8 48·0	+1·7	...

Reduced lat. + 4″·9.

The Equatorial Belt.

The two heavy belts on either side of the equator I designate the Equatorial Belt. During the past twenty years, systematic observations have been made of the position angle and latitude of the north edge, together with the total width of both portions

of the belt. During the past four years the width of each part of the belt has also been measured separately. In the Table of Observations :

P=position angle north edge.
β=distance from the apparent equator.
W=total width of the belts.
N=width of the north part.
S=width of the south part.
Long=Longitude in time from Marth-Crommelin Meridian...II.

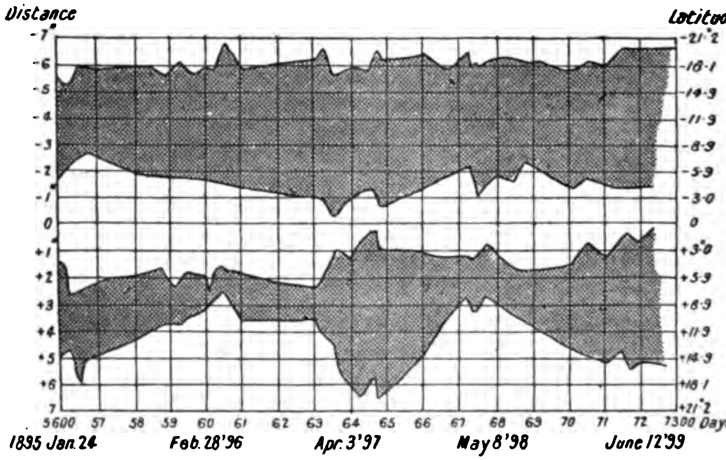
After correcting the apparent distances for the elevation of the Earth above *Jupiter's* equator, the diagram was plotted.

But on account of the short time scale only enough observations have been used to show the general displacement in latitude. It would of course be preferable to study the disturbance at the same longitude, but the observations are not sufficiently numerous for this purpose.

The diagram shows the position and magnitude, at any instant, of the two heavy belts on either side of the equator, which are designated the Equatorial Belt.

The numbers on the left are seconds of arc measured from the true equator ; those on the right, Jovicentric latitude.

The time intervals are each 100 days, and are counted from 1879 September 25. The dates at the bottom are given for every 400 days, 1895 January 24 corresponding to 5,600 days.



The diagram as plotted represents the average latitude and width of the belt around the whole circumference of the planet. If, however, the latitudes corresponding to any particular longitude are plotted, the curve will not vary materially from the diagram.

This diagram is of interest in showing at a glance the displacement in the material composing the two portions of the belt. In general, disturbances take place nearly at the same time on both sides of the planet's equator.

During the four years covered by these observations the north edge of the north belt shifted more than 3″ of arc, or 9 degrees of Jovicentric latitude; the inner edge, which is not well defined, shifted about 2″, or 6 degrees. The south belt showed less fluctuation in latitude.

During the opposition of 1896 the north belt became very narrow—at times less than 1″ of arc in width—and remained pretty constant for more than 400 days. In 1897 it widened out to about 5″ of arc. It remained wide for 300 days, then narrowed to 1″·5, and again widened in 1899.

Whenever a change took place in the width of the belt the expansion or contraction seems to have been nearly symmetrical on both edges of the belt.

During the four years the centre of the north belt remained in approximately the same latitude—viz. +2″·5. Whether the centre of the belt remains stationary in latitude I am unable to answer, as my latitude measures in former years are confined to the outer edges of the belt only.

In 1897 both the north and south portions nearly reached the equator, and the open space between the belts was less than 2″ of arc. Now the question naturally arises, What became of the dark material composing the belts during the changes in magnitude? Was it submerged, and so became invisible, or was it an actual dissipation of the matter of which it was composed? I am as yet unable to answer the question.

An examination of the measures seems to show that the drift in latitude of the outer edges of the Equatorial Belt does not occur simultaneously through the whole circumference of the planet. The edges of the belt, however, remain practically parallel to the equator in all longitudes, as may be inferred from an examination of the position angles. I have noticed two marked exceptions, however. On 1882 October 3 there was a curved projection in longitude $+0^h\ 30^m$ following the great Red Spot. On October 14 the edge was smooth at the same longitude, and the whole belt had drifted so far north as to coalesce with B_3. Also on 1897 February 24, in longitude $+5^h$, the preceding half of the north edge of the belt had drifted about 2″ further north than the following portion. On February 27, however, the edge of the belt was comparatively smooth in the same longitude.

The mean position angle of the north edge of the belt referred to the equator of the planet as given in Marth-Crommelin Ephemerides was as follows :—

Date.	Obs.—Eph.	No. Obs.
1896	+0°·34	18
1897	+0·24	16
1898	+0·78	13
1899	+0·88	18
Mean for 20 years	+0·23	

The maximum mean inclination was during the opposition of 1895 +1°·2.

It is extremely rare to find a marking inclined at any considerable angle to the equator.

While the displacement in latitude of the north edge of the equatorial belt has been so great, the black spots which have appeared near the margin of the belt since 1890 show very slight change in latitude from year to year.

From 1890 to 1899 the spots varied in latitude only 0″·57, while during the same period the north edge of the belt shifted 3″·7. Hence I infer that the spots lie at a different level—probably lower.

The Equatorial Belt.

Date.	P.	β.	W.	N	S.	Long.
1895.	°	″	″			h
Sept. 16	105·5	+3·90	10·08	...	...	+2·0
Oct. 29	107·1	3·62	9·73	...	...	4·3
Nov. 4	108·5	3·63	9·44	1·98	4·09	6·7
Dec. 9	107·0	4·11	10·13	1·18	4·16	6·1
15	107·3	3·53	9·41	...	...	0·2
21	107·9	3·34	10·08	1·62	4·74	6·9
30	105·7	3·14	...	...	...	4·8
1896.						
Jan. 6	106·8	3·35	9·15	1·86	4·44	2·8
9	106·3	3·59	9·71	1·88	4·43	4·4
13	...	3·70	9·55	...	...	2·0
29	105·0	3·77	...	1·30	4·34	8·0
30	105·4	3·13	...	...	...	1·5
Feb. 5	...	3·70	9·74	1·43	3·85	6·0
8	106·0	2·89	9·06	...	...	9·7
11	105·0	3·54	9·42	...	...	1·7
28	104·0	3·08	9·27	1·31	4·43	1·2
Mar. 2	104·5	4·02	...	...	...	5·0
3	104·4	3·22	9·55	...	...	8·7
4	...	3·19	9·58	0·66	3·92	2·5
16	104·6	2·95	8·92	1·48	4·24	3·4
19	...	3·02	9·26	...	...	6·3
23	...	+3·02	9·03	...	...	1·8

Date.	P.	β	W.	N.	S.	Long.
1896.	°	″	″			h
Apr. 2	...	+2·99	9·02	0·67	4·11	6·0
3	...	2·82	8·75	...	...	0·0
6	...	2·88	8·81	0·82	3·96	0·6
21	104·0	2·33	9·41	1·02	3·78	3·2
May 2	104·8	2·80	9·28	0·74	4·19	8·5
9	...	3·29	9·54	0·95	4·28	8·5
25	...	2·59	9·11	1·25	4·19	5·5
26	...	3·29	...	...	...	8·6
June 5	...	3·43	9·41	...	...	1·5
Dec. 12	...	3·90	9·80	...	...	7·4
1897.						
Jan. 17	113·5	4·42	10·68	1·20	5·50	7·4
20	114·4	4·59	9·96	...	4·96	1·0
Feb. 2	114·4	3·35	8·45	0·90	4·98	2·0
13	...	4·80	9·82	...	...	9·3
20	112·8	5·11	10·45	2·70	5·40	6·4
24	113·4	4·49	10·45	...	...	5·0
27	113·5	6·23	10·62	...	...	5·0
Mar. 1	114·7	5·72	11·21	4·15	5·54	5·0
3	114·0	6·62	11·25	4·04	4·87	3·0
10	...	6·25	11·36	3·52	4·98	2·0
12	...	6·01	11·33	...	...	1·1
15	...	5·23	11·39	3·77	4·99	3·0
20	113·5	5·94	11·50	3·92	5·48	3·1
Apr. 9	113·8	6·33	12·01	4·66	4·93	6·5
10	...	6·10	11·42	...	...	3·0
16	...	6·03	12·22	5·98	5·02	7·0
23	113·8	6·17	12·79	5·11	5·68	5·0
24	113·1	6·29	12·44	5·83	5·48	0·1
May 16	113·8	6·87	12·64	5·59	5·25	1·0
24	112·9	6·44	11·75	5·42	5·27	4·0
26	...	5·95	...	...	...	3·1
30	...	5·82	...	5·38	5·16	8·9
June 1	113·9	6·26	12·03	...	...	7·0
2	...	6·01	12·24	5·72	5·72	2·0
7	...	6·00	12·71	6·18	6·18	2·7
12	...	6·05	12·42	4·90	4·90	4·0
21	...	6·32	11·98	5·66	5·66	8·9
22	113·4	6·55	12·71	5·54	5·65	5·0
29	...	+6·73	12·76	...	...	4·1

R. R.

Date.	P.	β	W.	N.	S.	Long.
1897.	°	"	"			h
Oct. 25	115·3	+5·51	11·35	...	...	3·0
1898.						
Jan. 13	...	3·96	9·00	...	...	0·0
Feb. 13	...	3·79	9·66	1·74	4·49	5·0
26	114·5	3·63	9·37	1·67	5·10	6·1
Mar. 2	...	4·00	8·85	...	...	2·5
4	...	4·08	9·55	...	...	0·0
7	...	3·97	9·42	2·05	4·63	2·0
13	...	4·02	8·61	1·80	4·45	7·8
16	...	4·91	8·99	...	...	2·5
19	116·3	4·23	9·41	2·06	4·93	2·6
28	...	3·61	9·57	...	...	0·1
30	116·8	3·93	8·66	1·90	4·83	8·4
Apr. 5	...	3·62	8·81	1·88	4·39	1·0
11	116·1	3·61	9·33	2·17	4·09	7·9
15	115·7	4·03	9·72	...	...	4·8
20	116·1	3·81	9·13	1·81	4·02	4·0
30	116·5	4·02	9·60	...	...	6·0
May 3	...	4·23	9·72	2·56	5·01	8·9
7	118·8	4·10	9·66	1·91	4·19	5·5
21	118·1	3·76	9·65	...	...	5·0
23	116·0	3·62	9·45	...	...	3·1
30	116·7	3·31	9·47	...	...	3·0
June 4	116·2	3·79	8·93	1·34	4·45	2·9
14	114·8	3·74	...	2·02	5·01	4·7
28	117·0	3·84	9·27	1·16	4·73	3·3
July 6	...	4·10	9·51	...	...	6·3
16	...	4·20	9·90	1·87	3·84	7·6
Dec. 10	...	5·79	10·68	3·23	4·32	0·0
1899.						
Jan. 14	...	5·46	10·61	4·32	4·32	6·0
Feb. 28	...	4·65	10·00	...	...	0·1
Mar. 13	...	[6·25]	[11·73]	...	...	6·5
23	112·8	5·92	10·49	3·82	4·74	2·5
28	...	5·66	10·58	...	...	4·5
Apr. 3	111·6	5·76	11·36	...	...	8·4
4	111·4	5·54	10·96	...	...	2·7
7	...	5·54	11·02	...	...	5·2
8	111·3	5·49	11·03	...	...	8·3
23	...	+5·84	11·58	...	...	0·8

Date. 1899.	P.	β	W.	N.	S.	Long.
	°	"	"			h
Apr. 25	112·1	+4·96	10·30	3·67	4·50	0·0
28	112·8	6·45	11·14	4·50	5·10	4·0
May 1	...	5·98	11·31	...	...	3·7
4	112·1	6·51	11·65	4·68	4·94	6·9
8	...	5·79	11·02	...	...	4·0
10	...	6·07	11·70	...	...	3·5
17	112·1	6·44	12·30	5·47	5·52	1·5
18	...	6·27	11·98	...	...	7·0
27	112·1	6·60	11·54	4·26	5·03	2·0
29	...	6·05	11·08	...	...	1·0
30	...	6·39	...	...	...	4·1
31	...	6·08	11·00	...	...	8·9
June 3	...	6·08	10·50	...	...	1·0
7	111·5	6·10	11·94	4·81	4·21	8·9
9	111·6	6·63	11·19	...	...	6·7
10	111·7	6·20	12·14	5·59	4·92	2·0
11	...	6·16	11·55	...	...	5·6
13	...	5·58	11·35	4·41	4·55	4·1
16	...	6·16	11·54	...	...	6·0
20	...	5·87	11·44	4·63	4·91	3·1
21	...	5·97	11·28	...	...	7·0
23	...	6·16	11·85	...	...	6·5
24	110·9	6·20	11·62	...	...	0·0
25	...	6·68	11·85	5·39	5·39	2·4
26	...	5·86	11·47	...	...	7·9
29	...	6·16	11·87	...	...	0·0
30	111·9	6·23	11·64	...	...	3·5
July 5	...	6·15	...	...	...	4·6
8	...	6·47	11·26	4·64	4·88	6·5
11	111·9	6·63	11·70	...	...	0·0
17	111·9	6·12	12·06	5·04	5·04	4·6
19	...	6·37	12·16	...	...	3·0
21	...	6·30	12·22	...	...	0·1
29	...	6·12	11·90	...	...	4·2
Aug. 9	111·9	6·38	12·52	...	...	0·0
25	110·7	+6·10	11·90	...	...	6·0

The following are the mean values for the reduced latitude of the north and south edges of the Equatorial Belt during each opposition :—

Reduced Latitude.

Mean Day.		N. Edge.	No. Obs.	S. Edge.	No. Obs.
		"		"	
1896 Mar. 1	6001	+3·44	20	−5·97	20
1897 Apr. 11	6408	+5·30	29	−6·10	27
1898 11	6773	+3·16	27	−6·16	26
1899 May 23	7180	+5·06	48	−6·36	46

Conclusions.

1. The surface density of the planet *Jupiter* is presumably less than one-half that of water. The experiments made during the past twenty-five years in the liquefaction of air and gases enable us to imagine a plastic medium of the probable density of the planet.

If, then, the objects we observe are located at different levels in this medium, it would enable us to understand better why spots in the same latitude give different rotation periods.

2. The great Red Spot, 27,000 miles long, 8,000 miles wide, and possibly as deep as it is wide, drifts in both longitude and latitude.

It is the most stable of any marking seen on the disk. Its visibility may depend on its greater or less submergence beneath the surface, and its rate of drift (rotation period) may also be due to the same cause.

3. The rotation of the whole surface of the planet, on which spots or markings have been observed, is performed in $9^h\ 55^m$ to 56^m. The true rotation of the planet, however, may be slower than the longest rotation period hitherto observed, in which case all objects would drift in the same direction. My observations during the past twenty years extend from $+37°$ to $-38°$ of jovicentric latitude. Very few rotation periods have ever been determined outside these limits.

4. The rotation period is not constant for any latitude, but usually varies with the time.*

5. There is apparently no direct connection between latitude and rotation period, as is sometimes alleged.†

6. The rotation periods determined from spots or markings lying in the same latitude and at the same opposition may differ *inter se* 30 seconds or more. Hence the conclusions deduced by some observers for various permanent currents *on the surface of* the planet are based on insufficient data.

7. In the equatorial region from $+11°$ to $-8°$ of jovicentric latitude is found a rotation period $9^h\ 50^m \pm$, and this shorter period may possibly extend to 20° of latitude.

* Vide *A.N.* 3354.

† Vide *P.A.*, February 1899, Table of Rotation Periods.

8. The periods $9^h\ 55^m+$ and $9^h\ 50^m\pm$ are found in the same latitude, and probably at the same time.

9. It seems to me that the complicated motions observed on the surface of the planet are best explained by assuming the existence of a number of layers, or strata, at different depths below the surface, in which are located the objects under observation.

Observations of Minor Planets at Windsor, N.S. Wales. By John Tebbutt.

The accompanying observations have been made with the filar-micrometer on the 8-inch equatorial refractor, and in a bright field. The reductions have been made with a new and improved value ($17''\cdot813$) of a revolution of the micrometer screw, and the differential coordinates have been corrected for refraction and a small error in the perpendicularity of the micrometer threads. The corrections to the ephemeris of *Vesta* in the *Nautical Almanac*, and to that of *Iris* in the *Ast. Jahrbuch* have been kindly supplied by Mr. Merfield, F.R.A.S., of Sydney. The observations of the latter planet have been made expressly for Dr. J. Riem's proposed improved tables of *Iris*.

Observations.

(4) *Vesta.*

1899.	Windsor Mean Time.	Planet—Star. Δ R.A.	Planet—Star. Δ N.P.D.	Comps.	Reductions to App. Place R.A.	Reductions to App. Place N.P.D.	Planet's Apparent R.A.	Planet's Apparent N.P.D.	Log p Δ for R.A.	Log p Δ for N.P.D.	Star.	Obs.—Cal. R.A.	Obs.—Cal. N.P.D.
	h m s	m s	′ ″		s	″	h m s	° ′ ″				s	″
Oct. 31	8 38 17	+5 26·50	−8 30·4	10	+4·69	−27·4	1 20 58·14	93 37 39·9	9·4067n	0·6494	1	+2·15	−12·9
Nov. 1	8 25 49	+4 37·24	−6 30·5	10	+4·69	−27·3	1 20 8·88	93 39 39·9	9·4300n	0·6500	1	+2·17	−13·5
7	8 59 30	+0 1·20	+1 14·0	15	+4·69	−26·8	1 15 32·84	93 47 24·9	9·1729n	0·6430	1	+2·05	−13·0
8	8 5 10	−0 38·65	+1 43·8	20	+4·69	−26·7	1 14 52·99	93 47 54·8	9·3924n	0·6471	1	+2·03	−14·2
9	8 52 33	−1 20·15	+2 3·9	10	+4·69	−26·7	1 14 11·49	93 48 14·9	9·1592n	0·6427	1	+1·98	−14·1
10	7 47 24	−1 56·91	+2 10·1	7	+4·69	−26·6	1 13 34·73	93 48 21·2	9·4196n	0·6480	1	+1·84	−13·9
14	9 24 1	−4 19·80	+0 26·7	9	+4·68	−26·3	1 11 11·83	93 46 38·1	8·4722n	0·6410	1	+1·94	−13·4

(7) *Iris.*

1899.	Windsor Mean Time.	Planet—Star. Δ R.A.	Planet—Star. Δ N.P.D.	Comps.	Reductions to App. Place R.A.	Reductions to App. Place N.P.D.	Planet's Apparent R.A.	Planet's Apparent N.P.D.	Log p Δ for R.A.	Log p Δ for N.P.D.	Star.	Obs.—Cal. R.A.	Obs.—Cal. N.P.D.
	h m s	m s	′ ″		s	″	h m s	° ′ ″				s	″
Oct. 17	10 36 38	−0 15·16	−16 38·3	20	+4·91	−28·9	1 12 47·91	71 40 10·7	9·0747n	0·8377	2	+2·03	− 6·8
18	10 11 0	−1 0·92	− 8 57·7	20	+4·92	−28·9	1 12 2·16	71 47 51·3	9·2156n	0·8333	2	+2·11	− 7·1
23	9 30 1	−5 46·93	...	3	+4·94	...	1 8 18·04	...	9·3026n	...	3	+2·34	...
23	9 30 1	−6 43·26	...	3	+4·94	...	1 8 18·22	...	9·3026n	...	4	+2·52	...
23	9 30 1	−7 10·49	+10 26·5	3	+4·94	−29·2	1 8 17·62	72 28 50·6	9·3026n	0·8254	5	+1·92	−12·4
25	9 12 21	−3 59·05	− 7 17·9	5	+4·92	−29·6	1 6 53·64	72 46 7·7	9·3380n	0·8218	6	+2·19	− 7·7
31	10 0 14	−2 40·59	− 5 30·0	10	+4·90	−30·1	1 3 6·62	73 39 31·4	8·7397n	0·8285	7	+2·29	−10·8
31	10 0 14	−4 26·18	− 6 13·3	10	+4·91	−30·0	1 3 6·03	73 39 33·5	8·7397n	0·8285	8	+1·70	− 8·7
Nov. 1	9 51 41	−3 12·84	+ 3 18·8	10	+4·90	−30·2	1 2 34·37	73 48 20·1	8·8055n	0·8274	7	+2·35	−11·5
1	9 51 41	−4 58·44	+ 2 35·4	10	+4·91	−30·1	1 2 33·77	73 48 22·1	8·8055n	0·8274	8	+1·75	− 9·5
7	10 25 20	+2 9·35	+16 47·8	10	+4·85	−30·7	0 59 55·54	74 40 35·7	8·8429	0·8214	9	+2·00	− 9·3
9	10 7 18	−3 17·22	...	10	+4·86	...	0 59 18·92	...	8·6833	...	10	+2·09	...
9	10 7 18	−5 36·12	+ 5 44·7	10	+4·87	−30·4	0 59 18·83	74 57 3·1	8·6833	0·8203	11	+2·00	− 8·4
17	8 52 37	+3 46·04	+ 0 59·6	15	+4·77	−30·8	0 58 16·11	75 56 35·8	8·6567n	0·8135	12	+1·73	− 6·0
18	8 35 46	+3 48·01	+ 7 33·5	15	+4·77	−30·8	0 58 18·08	76 3 9·7	8·8686n	0·8120	12	+1·76	− 6·3
19	8 40 41	+3 52·22	+14 2·2	15	+4·76	−30·8	0 58 22·28	76 9 38·4	8·7369n	0·8118	12	+1·85	− 4·9
20	9 7 26	−0 8·45	−19 48·9	20	+4·77	−30·4	0 58 28·35	76 15 59·9	8·1175	0·8117	13	+1·51	− 3·8

1899.	Windsor Mean Time.	Planet—Star. Δ R.A.	Planet—Star. Δ N.P.D.	Comps.	Reductions to App. Place R.A.	Reductions to App. Place N.P.D.	Planet's Apparent R.A.	Planet's Apparent N.P.D.	Log p Δ for R.A.	Log p Δ for N.P.D.	Star.	Obs.—Cal. R.A.	Obs.—Cal. N.P.D.
	h m s	m s	′ ″		s	″	h m s	° ′ ″				s	″
Nov. 23	9 0 53	+0 23.95	− 2 32.7	20	+4.75	−30.4	0 59 0.73	76 33 16.1	8.3716	0.8097	13	+1.61	− 4.8
24	9 1 33	+0 39.18	+ 2 45.5	20	+4.75	−30.4	0 59 15.96	76 38 34.3	8.5193	0.8088	13	+1.66	− 5.3
25	8 52 32	+0 56.43	+ 7 48.4	15	+4.74	−30.4	0 59 33.20	76 43 37.2	8.3286	0.8083	13	+1.64	− 4.8
26	8 42 40	+1 15.86	+12 35.8	15	+4.73	−30.4	0 59 52.62	76 48 24.6	7.8748	0.8080	13	+1.66	− 5.5
27	9 0 17	+1 37.85	+17 14.7	15	+4.73	−30.4	1 0 14.61	76 53 3.5	8.7332	0.8068	13	+1.72	− 5.5
28	9 11 58	+7 57.42	+ 6 57.8	8	+4.69	−30.5	1 0 38.62	76 57 27.5	8.9414	0.8053	14	+1.70	− 4.5
Dec. 5	9 10 8	+3 5.12	−13 38.8	10	+4.68	−29.8	1 4 24.54	77 20 58.8	9.1285	0.8000	15	+1.47	− 3.7
8	9 26 10	+5 13.13	− 7 16.1	10	+4.66	−29.6	1 6 32.53	77 27 21.7	9.2740	0.7954	15	+1.54	− 4.1
12	8 44 54	+2 35.72	+ 3 4.5	14	+4.67	−29.2	1 9 47.75	77 32 25.2	9.1066	0.7990	16	+1.44	− 5.6
14	8 24 12	+4 24.04	+ 4 14.9	10	+4.65	−29.2	1 11 36.05	77 33 35.6	8.9834	0.8004	16	+1.33	− 5.3
16	9 14 50	+6 22.08	+ 4 31.9	10	+4.63	−29.1	1 13 34.07	77 33 52.7	9.3313	0.7919	16	+1.29	− 5.1
17	8 57 54	+7 22.01	+ 4 21.2	10	+4.62	−29.1	1 14 33.99	77 33 42.0	9.2697	0.7946	16	+1.30	− 4.5
22	8 53 28	+4 26.77	− 9 55.8	10	+4.63	−28.3	1 20 0.83	77 29 39.7	9.3138	0.7933	17	+1.48	− 3.6
23	9 15 32	+5 37.79	−11 22.5	8	+4.62	−28.3	1 21 11.84	77 28 13.0	9.4061	0.7880	17	+1.46	− 4.4
25	8 38 57	−3 54.28	+ 3 52.9	10	+4.69	−27.6	1 23 34.35	77 24 52.1	9.2865	0.7951	18	+1.36	− 4.5
26	8 22 55	−2 40.82	+ 1 56.3	10	+4.68	−27.5	1 24 47.80	77 22 55.6	9.2202	0.7976	18	+1.29	− 4.0
29	8 52 36	+1 12.08	− 5 6.6	20	+4.65	−27.4	1 28 40.67	77 15 52.8	9.3834	0.7908	18	+1.33	− 4.9
30	9 2 36	+2 32.45	− 7 47.6	12	+4.64	−27.3	1 30 1.03	77 13 11.9	9.4247	0.7879	18	+1.34	− 4.2

Mean Places of the Comparison Stars for 1899·0.

Star.	R.A. h m s	N.P.D. ° ′ ″	Authorities.
1	1 15 26·95	93 46 37·7	Yarnall$_2$, 677; Argent. Gen. Cat. 1258; Radcliffe, 1890, 310.
2	1 12 58·16	71 57 17·9	Wash. Gen. Cat. 1875, 310; Radcliffe, 1890, 304; Cincinnati, 1890, 185.
3	1 14 0·03	...	Lalande, 2369.
4	1 14 56·54	...	Lalande, 2400–1.
5	1 15 23·17	72 18 53·3	Lalande, 2411–4; Cincinnati, 1890, 192.
6	1 10 47·77	72 53 55·2	Wash. Gen. Cat. 1875, 298; Radcliffe, 1890, 296; Cincinnati, 1890, 181.
7	1 5 42·31	73 45 31·5	Lalande, 2103.
8	1 7 27·30	73 46 16·8	Lalande, 2158.
9	0 57 41·34	74 24 18·6	Wash. Gen. Cat. 1875, 236; Radcliffe, 1890, 226; Cincinnati, 1890, 138.
10	1 2 31·28	...	Wash. Gen. Cat. 1875, 265; Radcliffe, 1890, 257; Cincinnati, 1890, 151.
11	1 4 50·08	74 51 48·8	Wash. Gen. Cat. 1875, 279; Radcliffe, 1890, 267; Cincinnati, 1890, 164.
12	0 54 25·30	75 56 7·0	Wash. Gen. Cat. 1875, 222; Radcliffe, 1890, 212; Cincinnati, 1890, 129.
13	0 58 32·03	76 36 19·2	Radcliffe, 1890, 230; Cincinnati, 1890, 140.
14	0 52 36·51	76 51 0·2	Yarnall$_2$, 506; Wash. Gen. Cat. 1875, 212; Greenwich, 1880, 149; Radcliffe, 1890, 202; Cincinnati, 1890, 126; Glasgow, 1890, 76.
15	1 1 14·74	77 35 7·4	Greenwich, 1880, 177; Radcliffe, 1890, 246; Glasgow, 1890, 86.
16	1 7 7·36	77 29 49·9	Yarnall$_2$, 626.
17	1 15 29·43	77 40 3·8	Yarnall$_2$, 676.
18	1 27 23·94	77 21 26·8	Lalande, 2806.

Observatory, Peninsula, Windsor, N.S. Wales:
1900 *March* 10.

Supplementary Observations of Minor Planet (7) *Iris.*

By John Tebbutt.

In addition to the equatorial observations of (7) *Iris* already forwarded, the planet was observed four times on the meridian with the 3-inch transit instrument, with the following results. The corrections (Obs.–Cal.) to the *Jahrbuch* Ephemeris have been kindly furnished by Mr. Merfield.

Windsor Mean Time, 1899. d h m s	Approx. R.A. of Planet. h m s	Correction to Ephemeris. s
Nov. 18 9 9 12	0 58 18·17	+1·86
25 8 42 56	0 59 33·20	+1·74
28 8 32 12	1 0 37·91	+1·59
Dec. 1 8 21 48	1 2 1·98	+1·61

Observatory, Peninsula, Windsor, N.S. Wales:
1900 *April* 2.

Errata in Mr. Tebbutt's Papers.

Vol. lviii. page 467, line 10 from top, *for* extend *read* entered.

" lix. " 543, " 21–22 from top, *for* catalogue, in two places, *read* catalogues.

" lix. " 543, " 26 from top, *for* 1 *read* 71.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX. JUNE 8, 1900. No. 9

E. B. KNOBEL, ESQ., PRESIDENT, in the Chair.

Louis Napoleon George Filon, M.A., Fellow of and Assistant Professor of Applied Mathematics at University College, London, Godwin House, St. Augustine's Avenue, South Croydon;

Forest Ray Moulton, Ph.D., Instructor in Astronomy at the University of Chicago; and

William Harrison Pearsall, Higher Grade School, Dalton-in-Furness, were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Sri Rajah Ankithum Venkata Jugga Row Bahadur, Yambram Estates, Vizagapatam, India (proposed by E. B. Knobel); and

Ernest H. Shackleton, R.M.S. *Tintagel Castle* (proposed by Thomas Lewis).

Fifty-two presents were announced as having been received since the last meeting, including, amongst others :—

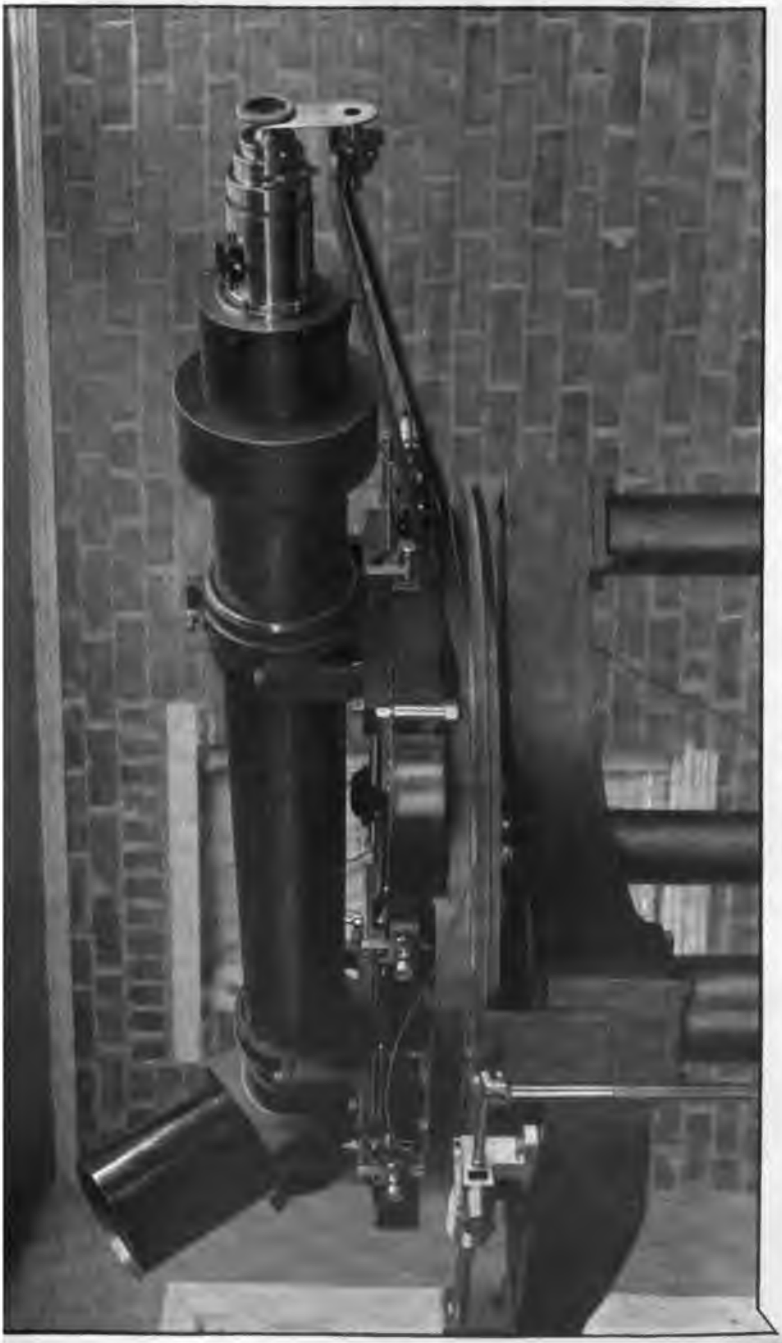
Memoirs presented to the Cambridge Philosophical Society on the occasion of the Jubilee of Sir G. G. Stokes, presented by

the Society; G. W. Hill, On the extension of Delaunay's method in the Lunar theory to the general problem of planetary motion, presented by the author; W. E. Wilson, Astronomical and physical researches made at Daramona, Westmeath, presented by the author; Astronomischer Jahresbericht, Band 1, enthaltend die Literatur von 1899, presented by the editor, Dr. W. F. Wislicenus; Yerkes Observatory Publications, vol. i. (Burnham, General Catalogue of Double Stars), presented by the Observatory.

Description of the Durham Almucantar. By Professor R. A. Sampson.

In the year 1884 Mr. S. C. Chandler set up at Cambridge, U.S.A., a transit instrument of a novel design, and made observations with it on time, latitude, and coordinates of stars for the space of about a year, in connection with Harvard College Observatory. A description of his instrument, its theory, and details of his observations are given by Mr. Chandler in vol. xvii. of the *Harvard Annals.* He named it Almucantar from the fact that it took transits across a horizontal circle, or almucantar, in place of across the meridian. Briefly, the principle of his design is to abolish adjustment and correction of the axis of rotation of his telescope by using the automatic action of gravity, and this he effects by clamping the telescope to a tray which floats on a trough containing mercury. Lateral motion of the float is prevented by stops, which are contrived so as not to interfere with the float taking up its own level, and accidental disturbance of the mercury is allowed to settle before the observation is made. If then the trough is rotated in azimuth, the axis of the telescope settles down to point always to the same horizontal circle on the sky, across which transits may be taken in the usual way. Every star which crosses this circle transits twice, once east and once west of the meridian, at azimuths which may be computed beforehand for the purpose of setting the instrument. From these we get two time observations, which determine the coordinates of the star, or, in the case of known stars, the instrumental errors.

Mr. Chandler's telescope was about 4 inches aperture and 43 inches focal length. His float was made of detached pieces of cherry wood, braced together with a brass frame, somewhat irregular in plan, like the letter E *minus* its middle stroke. The telescope hung over one side of the float, counterpoises being attached to the other side to keep it level. The whole floating piece weighed 31 lb. A second instrument, similar in all essentials to Mr. Chandler's, was made at the same time, and the two, I believe, are now in use, in the hands of Professor W. V. Brown of McKim Observatory, and Mr. Charles H. Rock-



well of Tarrytown, N.Y., for the ordinary services of a transit circle, but not, I think, directed to the solution of any special problem.

It was on the advice of Professor Turner and Dr. Common that the Curators of the University Observatory at Durham decided to set up an almucantar. Without their generous help I would often have been at a loss in carrying out the plan. To Dr. Common especially we are in most substantial debt. The *coudé* design is essentially his; moreover he gave us the 9-inch flat mirror, and he sketched the proper form of dome to use.

The instrument was made by Messrs. T. Cooke & Sons, and is, I think, a piece of work thoroughly worthy of the firm. Much of the detail of the design is theirs.

The house in which the almucantar is set up consists of two rooms, each 14 feet square, lying east and west of each other. Nearly the whole of the roof of the east room is built to run on rails over the roof of the west room, leaving a square opening which commands about 45° from the zenith in all directions. In the middle of this room, and clear of the floor, a pier 4 feet square is built up from the bottom of a pit 5 feet deep. This is topped with a massive stone, upon which the instrument is placed, the tube of the telescope lying horizontally with the eye-piece at a convenient height for a standing observer.

The floating parts weigh about 4 cwts., the whole instrument about 1 ton. The stand, trough, and float are made of cast iron; the telescope tube of riveted steel; the azimuth circle of brass.

The stand is a tripod with adjusting screws for feet; at its centre it carries a vertical axis which is guided by two finely turned gun-metal collars, 20 inches apart. The upper collar is cone-shaped, but the chief share of the weight of the moving parts is taken off this collar by a counterpoise. The axis carries, first, an azimuth circle, 40 inches in diameter, divided to 20′ and read by two verniers to 1′, and operated, when clamped, by a worm working in teeth cut in the edge of the circle. There are two slow-motion rods which can be worked when the observer is at the north and south positions respectively. To the frame of this circle the trough is bolted, rectangular in shape, with slightly rounded corners. Its outside measure is $38\frac{3}{4}$ inches long by $26\frac{3}{4}$ inches broad by $2\frac{1}{4}$ inches deep, and it is $\frac{5}{8}$ inch thick. It is provided with a tap for emptying it when necessary. There is $\frac{3}{4}$ inch clear space between the walls of the trough and those of the float on all sides, but to guard against accidental spilling of the mercury this space is all covered in except $\frac{1}{16}$ inch. To this portion of the instrument are attached a guard to keep the eye from touching the telescope when observing, electric switches, rheostat, &c., and two spirit levels for examining the verticality of the axis of rotation. On these levels 1 division $= 4''\cdot2$ approximately. It is found that the stand changes very little from day to day, and that it is easy to keep the axis within 1″ of the vertical.

In the trough is about 150 lb. of mercury, lying about $\frac{1}{4}$ inch deep beneath the float, and about 1 inch deep along the sides of the float.

The float is similar in shape to the trough, except that it is crossed by two longitudinal and three transverse walls, $\frac{3}{8}$ inch thick, to increase its rigidity. Its outside measure is 36 inches long by 24 inches broad by 2 inches deep, and it is $\frac{5}{8}$ inch thick. When floating, the top of its walls stands $\frac{1}{2}$ inch above the top of the trough. It is kept in its place by six stops. These stops have to fulfil the conditions of preventing lateral motion in two directions and rotation in azimuth, while offering no resistance to oscillations about a horizontal axis, and it is evident that these conditions are satisfied by a horizontal pressure at six points upon the plane of flotation. Such pressure is secured by substantial cast-iron brackets carried from the float outside the trough, and bearing by hard steel rounded adjustable points upon vertical agate faces attached to the outer walls of the trough. These points are screwed up so as to bear upon the agates at the level of the plane of flotation, and are screwed in so as to be just clear of simultaneous contact, and then a drop of oil is put upon the agate for the point to work upon. Four of the brackets are perforated by other screws, faced with leather, and moving vertically down upon the cover of the trough. The purpose of these screws is to limit or stop altogether the oscillations of the float; by screwing them down far enough the float may be lifted out of the mercury to any desired degree, and the instrument converted into an ordinary altazimuth.

Near the middle of the float terminals are fixed for attaching illuminating wires. These wires come from the sides of the trough, and in order that they shall not produce any pull upon the float, they are contrived in the form of a very weak spring which in its unconstrained position is clear of the terminal but as close to it as possible. The terminal is then screwed down upon the wire. When the leather-faced stops are screwed up, these terminals and the six steel points are the only solid points of connection between the float and the stand. The float is thus completely free to regain its old position after a disturbance.

At the two ends of the float are carried two Y's for bearing the telescope tube, each 2 inches broad and 22 inches from centre to centre. Each Y is provided with a clamp; the one near the eye end has also a slow-motion arrangement. When by help of this the telescope is set to the proper altitude (which in nearly every case is the apparent altitude of the pole), the other clamp is screwed down and the altitude cannot then be disturbed through a series of observations.

The telescope tube is a riveted steel tube, 6 inches internal diameter, $\frac{1}{16}$ inch thick, very stiff, and further stiffened by diaphragms. This carries at the O.G. end a cast-iron box, triangular in side elevation, the cell of the object glass being attached to one side of the triangle, and the cell of a plane

mirror to the hypotenuse. There is also a counterpoise for bringing the centre of gravity of this piece to lie in the axis of the telescope tube.

The object glass is 6 inches clear aperture. The mirror is necessarily larger, since it has to take the cone of rays obliquely at a point where it is hardly at all reduced in diameter.

The eye end is provided with the usual adjustments for focussing, and also with screws for making the wires horizontal. This is important, because it is only polar stars that transit all wires at their middle points. The eyepiece has no sliding motion; where it is necessary to extend the field of view it will be done by carefully changing the azimuth with the slow-motion handle. The lines in the focus are close together for chronograph use. Following Mr. Chandler's example, I have had them ruled upon a plate of glass, but this does not seem a success, and I am replacing the glass plate by the usual spider lines in five tallies of five lines each.

There is a large lead counterpoise upon the tube, near the eye end; and a smaller one, running on a screw, attached to the bed of the float.

The theory of this instrument is at first sight of a somewhat forbidding character, being in fact, for the case of the fiducial circle set upon the pole, the geometry of a spherical triangle which is approximately isosceles. It has, however, been put by Mr. Chandler into a workmanlike shape, which in the long run probably involves little more trouble than does the transit circle.

I have spoken of the fiducial circle passing through the pole. The telescope may indeed be used at any altitude, just as the transit circle may be used in any azimuth; but in all other cases the calculations involved appear to me quite prohibitive for continuous use, and I have not taken any pains to secure for my observing-room a range of sky much below the pole.

Just as with the transit circle, the fiducial line across which all transits are taken is the line traced out upon the sky by the line of collimation, but in the almucantar this fiducial line is horizontal. All that is necessary in order that a true horizontal circle should be traced is that the telescope and float should be one rigid piece which settles down after a disturbance to exactly the same position as before.

The procedure is generally as follows:—

We first of all compute for a star of given declination the azimuth and hour angle of its transits, and also the degree in which faults in the assumed declination, latitude, and instrumental setting on the pole would affect the time of a transit. For a large number of stars this is a comparatively heavy piece of work, but it may be done once for all for a given latitude, in a systematic way, for all declinations from 90° to the lowest that makes a transit.

Then, setting for any star at the computed azimuth and at a time shortly in advance of the time = R.A. $\pm$ computed hour

angle, we observe the correction to the computed time of transit, and this must be distributed among the various producing causes—incorrect coordinates of the star, errors in the clock, in assumed latitude, in assumed zenith distance of the fiducial horizontal circle. All this has been skilfully worked out by Mr. Chandler in a way that gives these quantities separately and with no great labour. I will only say here that we get the corrections of clock, latitude, and instrumental setting from fundamental stars, and that in order to correct the assumed coordinates of others, it is not necessary to take both their transits on the same night.

It thus appears that the instrument is a competitor of the transit circle. There are many members of the Society better qualified than I to criticise the performances of the transit circle, and the immense labour which has been spent upon the study of the best instruments makes it a thing very difficult to do; but seeing that, in spite of this, their performances are not wholly free from obscurity, there is evidently room for another instrument of equal or perhaps of greater accuracy, and presenting, as I hope to show, many advantages in build and in mode of use. I will consider shortly the most obvious of these, from their theoretical side.

In the transit circle the axis of rotation must lie horizontally in the meridian. In the almucantar it must be truly vertical. This it will be if the float recovers its old position exactly after a disturbance, such as must take place at each new setting in azimuth. Mr. Chandler considered that his almucantar recovered its position after disturbance within $\frac{1}{20}$ of a second of arc, and that a tilt of the trough, such as might be due to imperfect levelling, produced a tilt of the float in the opposite direction of about $\frac{1}{100}$ of the amount. My own experience, so far as it goes, is confirmatory of this exactness. I mounted a spirit level with which we take level error in transit circle observations upon the float, and then suddenly altered the tilt of the trough by more than $100''$ by screwing in one foot; the mercury ran to and fro beneath the float, but in about two minutes the spirit level settled down to exactly the same position as before. It was a favourable day, upon which the level was behaving steadily. The divisions of the level used are of value $1''{\cdot}5$, and it was read with a magnifier, in a good light. So far I have put no more searching test; but if we accept Mr. Chandler's measures, errors of this kind, occurring, if at all, as accidental errors in a single observation, must be dismissed as entirely impalpable, and by this we abolish two corrections which are theoretically inherent to any instrument of this class—namely, those which correspond to azimuth and level error in the transit circle.

Nor is this all. One of the obscurest points in the determination of zenith distances by the transit circle is the part played by anomalous departures from the mean refraction. It can only

be treated as an accidental error. But in the almucantar it is completely eliminated, at least so far as it is constant throughout one night. For it acts in the same way as an error in the assumed zenith distance of the line of collimation, and the sum of the two is determined from fundamental stars each night, and is, of course, treated as a single error.

A fourth advantage is that we do not employ a divided circle for determining the star's position. Two transits, east and west, give the two coordinates. This amounts to replacing error of reading a circle by error of taking a transit, and errors proper to a circle itself by errors of a clock. Were this the only advantage the almucantar offered I think it would be a great one. To take only one kind of error inherent to a divided circle—the actual errors of the divisions themselves. In the life of the Greenwich Transit Circle these have been estimated at different times at five different amounts, and the last-adopted amounts differ from those used from 1868–79, in five cases out of sixty by quantities not less than $0''\cdot 2$, and in sixteen cases by quantities not less than $0''\cdot 1$, and from those used from 1880–96 in three cases by not less than $0''\cdot 2$ and in nineteen cases by not less than $0''\cdot 1$. These differences are no doubt small, even when considered as two deliberate measures of the same quantities; yet they are comparable with the probable error of the clock as deduced from a fairly long night's observations; they are moreover only one and that the least obscure and the most liable to experiment of the errors to which a divided circle is subject. Others are more competent to judge this point than I, but it seems to me a substantial gain to replace these errors by a repetition of the errors of clock and transit, even though, as will appear presently, declinations are not determined by an almucantar with equal rigour over its whole range.

A fifth error which is entirely eliminated is that of flexure of the telescope tube. This again is a very obscure point in transit-circle observations; at Greenwich it is allowed for through the R—D discordance, but some writers deny that the R—D discordance is a function of the Zenith Distance at all.*

There are other advantages which, though not so easy to assess, appear to me to carry considerable weight. The first of these is the homogeneity of the observations. In the transit circle declination is found by one species of observation, R.A. and clock error by another, and both must be combined with an altogether different series, taken in other ways and at other times for measuring other instrumental errors. With proper care the faults of such a plan are no doubt small, but they render it almost impossible to locate the more minute and obscure errors with which the final result is affected. Now with the almucantar both coordinates of the star and all instrumental errors are determined from a perfectly homogeneous system of transits. This must conduce to the removal of obscurities.

* Eastman, *Ast. Journal*, vol. xxi. p. 8.

The last advantage I would mention is the attitude of the observer. It is certain that no one would adopt, unless he were compelled, the attitudes enforced by the ordinary observing couch. With the almucantar as we have it the observer looks horizontally before him, standing in a normal attitude, which is the same for all stars.

Against these advantages must be set certain disqualifications. The chief is the limitation of the field of work: no star below 19° 32′ N. declination will transit the circle across which my observations are to be made, so that, for example, the Sun, Moon, and planets cannot be continuously observed.

Again, there is a peculiarity of the observations which is not found in the transit circle: different stars do not transit the wires at the same angle; each cuts them at an angle equal to its own hour angle. What effect this may have upon the transits must be discovered hereafter.

I have said that the net result of an almucantar observation is an equation connecting observed correction to a computed time and desired corrections to clock, R.A., declination, &c. Hence, if we chart the reciprocals of the coefficients with which these quantities appear in this equation, we get an immediately comprehensible view of the amount of error involved by a given error in taking a transit, supposing that error allocated exclusively to each of the unknowns in turn.

The accompanying chart (Plate 19) shows these quantities, and also the azimuth setting for any declination. The errors shown are such as would be produced by an error of $0^s{\cdot}1$ in a transit; reading abscissæ for declination, we see, for example, that an error of $0^s{\cdot}1$ in the transit of a star of declination 30° would introduce an error of $0''{\cdot}48$ in a latitude determined from this observation, if we simultaneously took all the other quantities as correct. Hence we see that latitude, which it may be convenient to treat as a variable, is found with very great rigour from observations of south stars. In the same way the collimation error, being a correction to assumed zenith distance, is found fully as exactly from transits of north stars. Clock error will be best found from quicker-moving stars near the prime vertical.

The precision of determinations of declination varies considerably. It is at first high, but falls off rather rapidly. An error of $0^s{\cdot}1$ in a transit implies an error of $0''{\cdot}3$ at +20°, $0''{\cdot}8$ at +30°, $1''{\cdot}3$ at +40°, $1''{\cdot}6$ at +50°, $2''{\cdot}0$ at +70°, after which it is nearly constant. Some comparison of these with the transit circle may be made. For example, at Greenwich in 1897 the N.P.D. of *Polaris* was measured seventy times at its upper transit, and the average discordance of the mean from individual results was $\pm 0''{\cdot}8$, and this may be taken as a fair average of the Greenwich measures of N.P.D. At the same time if we take any long series of transits of quick-moving stars by the same observer, the average discordance from the mean indicated clock error was $\pm 0^s{\cdot}04$ or $\pm 0^s{\cdot}05$. If then I should succeed in taking transits

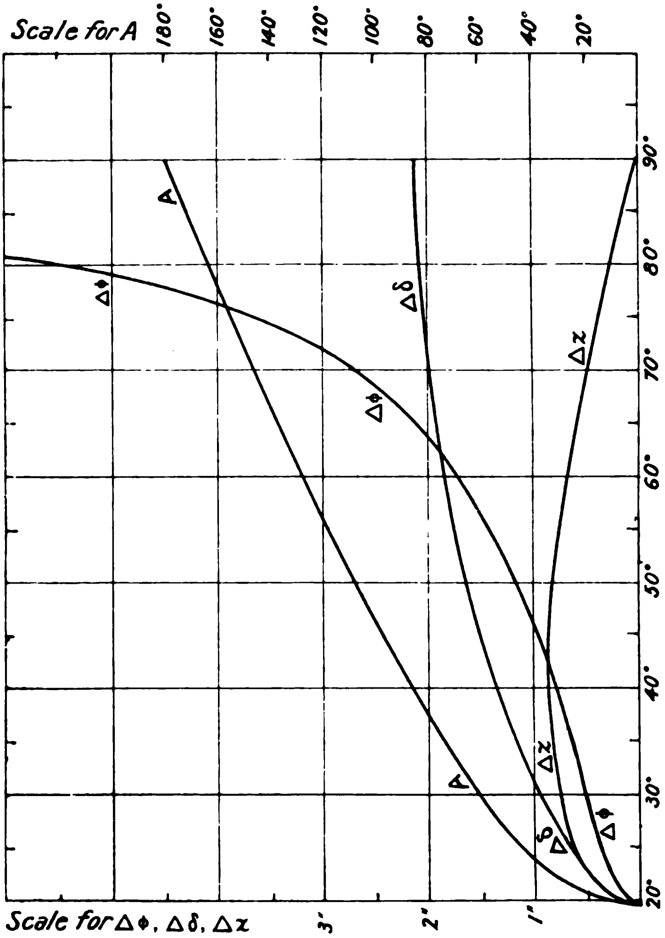


Chart of Almucantar Constants for Latitude of Durham Observatory (54° 46′ 6″·2 N).

Abscissa = declination of object.
Ordinates, A = azimuth at transit.
Δδ = error in deduced declination for $0^s{\cdot}1$ error in transit.

as correct as those of Greenwich, they would, of course, give Right Ascensions of equal exactness, while errors in declinations would be less from 20° to 50°, and above that somewhat greater. It is with hesitation that I give this estimate, because such forecasts are not of much value, and are open to the objection of seeming to claim credit for a status that has hereafter to be justified. My purpose is very different from that; it is to show that *prima facie* the almucantar has claim to be admitted of as great or greater precision than the transit circle, though over a somewhat more restricted range. It is not to be expected that it will prove an exception to invariable experience with new instruments, and yield results of the first rank of accuracy, without the cost of much thought and labour, although Mr. Chandler's early success with it is encouraging.

It is my intention in the first instance to test its performances by re-observing many times the transits of *Nautical Almanac* stars, of which 121 cross our circle of observation, with the intention of doing everything to increase, if possible, the fidelity of such fundamental points. Even if experience should hereafter suggest some other line as more profitable, I think time would be gained on the whole by first establishing thoroughly the character of the instrument and finding out its peculiarities by such a research.

The Effects of Stellar Rotation upon Spectrum Lines.

By A. Fowler.

The possible modification of the lines in a stellar spectrum by a rapid rotation of the star was first pointed out by Sir William Abney in 1877.* Provided that the axis is not directed towards the Earth, it is evident that the effect of rotation will be to broaden all the lines of the spectrum, since rays proceeding from the central meridian of the star disc will suffer no displacement on account of this motion, while those from the approaching and receding portions will be displaced by varying amounts towards the more and less refrangible ends of the spectrum respectively. Abney suggested that the finer lines of a spectrum might in this way be caused to disappear, and that the velocity of rotation might be derived from the observed amount of broadening. In the same year Vogel investigated the distribution of intensity in a line broadened in this manner,† but spectra satisfying the conditions were then unknown.

Many spectra in which all the lines are wide and ill defined have since been recorded, and in the case of *a Aquilæ* rotation has been adopted by Pickering, Lockyer, and Vogel as

* *Monthly Notices*, vol. xxxvii. p. 278.
† *Ast. Nach.* Bd. 90, p. 71.

providing a simple and sufficient explanation of the observed appearance of the spectrum.

In view of the possible importance of such effects in the interpretation of other peculiar spectra, it has been thought desirable to investigate more completely the conditions relating to the modifications of lines by stellar rotation, and the results of this inquiry are given in the present paper.

The displacement of a line, or of any portion of a broadened line, is in all cases proportional to the component velocity in the line of sight of the vapour producing it. The intensity of a line broadened by rotation at any point in its breadth will therefore be determined by the proportionate amount of vapour having corresponding component velocity.

Loci of Points of Equal Component Velocity.

(1) The component velocity in the line of sight of any point on or within a rotating rigid sphere is proportional to the perpendicular distance of the point from a plane containing the axis and the Earth. The component velocity is therefore the same for all points which lie in a plane perpendicular to the equator of the star and passing through the Earth.

Thus, in fig. 1 *a*, where the axis is perpendicular to the line of sight, the component velocities in the line of sight are equal for all points which lie along the circle ABD, or in its plane, and are represented by the distance CB if the equatorial velocity be represented by CE.

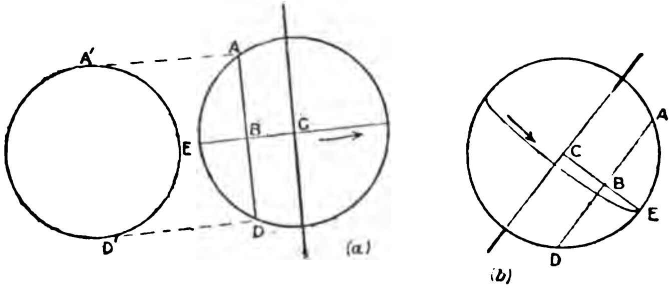


FIG. 1.—Illustrating circles of equal component velocities of rotating spheres.

When the axis is not perpendicular to the line of sight, as in fig. 1 *b*, the result is the same except that all the component velocities in the line of sight are reduced, the constant factor being the sine of the angle of inclination. If the axis be directed towards the Earth, the component velocities are zero, and there will be no broadening of the spectrum lines due to rotation.

Effects of Rotation upon Dark Lines.

(2) If the absorbing vapours all move with the same angular velocity, the amount of broadening of the lines will be independent of the distance above the photosphere of the vapours which produce them, but will in all cases be equal to that due to the component velocities of a layer close to the photosphere.

This follows from (1), since only the vapours lying between us and the photosphere are effective in producing dark lines.

(3) Assuming that a star appears as a uniformly illuminated disc, and that its spectrum is the same in all parts of the disc, the intensity at any point of a broadened absorption line is proportional to the diameter of the circle of equal and corresponding component velocity.

The intensity curve may be constructed by taking distances CB (fig. 1) as abscissæ and AD as ordinates, and will be a semicircle if the intensity at the middle of the line is represented by a length equal to that taken to represent the greatest displacement to either side. The numerical values may be easily calculated, and are as follows :—

Distance from Middle of Line.	Intensity.	Distance from Middle of Line.	Intensity.
±0·0	1·00	±0·6	0·80
0·1	0·995	0·7	0·71
0·2	0·98	0·8	0·60
0·3	0·95	0·9	0·44
0·4	0·92	±1·0	0·00
±0·5	0·87	...	...

On account of the rapid fall in intensity near the extreme edges, the amount of broadening actually observable will necessarily be somewhat smaller than that due to the equatorial velocity.

If there be any considerable absorption near the edges of the star disc the lines will fade away more rapidly.

(4) The displacement corresponding to the greatest component velocity observable is equal to half the difference in breadth of a broadened line and the breadth of the same line when not affected by rotation.

The finer lines will thus appear to be more widened than the thicker ones. Thus, if a particular line is widened to three times its own thickness, a line of half the normal thickness will be widened to five times its own breadth.

(5) Lines, such as those of hydrogen in a *Sirian* star, which fade off at the edges when not affected by rotation, will not have the same distribution of intensity as the more common type of lines.

Such a line may be regarded as built up of a number of components, each of which will be spread out into a broad band by the effect of rotation, and the ultimate form of the whole will be due to the integrated effects. The result will vary in individual cases, but in general the feeble edges of the lines will probably be so spread out that they will be ineffective in the final result; it may be expected, therefore, that the effect of rotation on such lines will be to make the lines less diffuse on the edges and perhaps not much wider than the corresponding line in a similar star which is unaffected by rotation. (This appears to be the case in α *Aquilæ*.)

(6) The effects so far described will be modified if the absorbing vapours move with different angular velocities in different latitudes, as in the case of the Sun.

In the Sun, according to the spectroscopic measurements of Dunér, the angular velocities of the absorbing vapours decrease regularly from the Equator to the Poles, so that the proportion of particles of low velocity will be increased as compared with a star in which the angular velocity is constant. There will accordingly be a greater relative intensity towards the middles of the broadened lines.

The loci of points of equal velocity in the line of sight will no longer be chords perpendicular to the Equator, but will be such that in projection they appear as in fig. 2, which is drawn to scale in accordance with Dunér's observations. The ordinates of the intensity curves of the lines will be proportional to the lengths of *cd*, *ef*, &c., and the abscissæ will be respectively proportional to the distances *xy*, *xz*, &c.

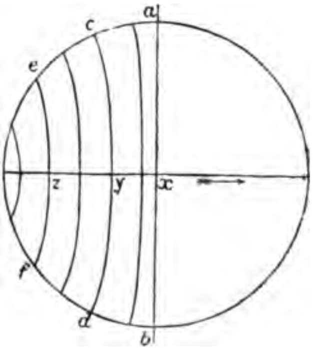


FIG. 2.—Loci of points of equal component velocities in the case of the Sun.

Effects upon Bright Lines.

In the case of bright lines the effects will generally differ from those produced in dark lines, but so little is yet known with certainty as to the conditions under which bright lines

become visible in stellar spectra that the effects of rotation can only be investigated under assumed conditions. Still, some of the possible effects appear to be of sufficient interest to deserve mention. In each case the conclusions are based on the supposition that the gases producing bright lines are completely transparent.

(7) If the bright lines proceed from shells of incandescent vapours, the amount of broadening due to rotation will not necessarily be the same for all the lines.

Assuming the same angular velocity for all the vapours, it is evident that those extending furthest from the centre will have the greatest velocities, and that the lines which they give will be subject to the greatest amount of broadening.

(8) In the case of a spherical shell of vapour, no part of which is obstructed from view, the intensity of a bright line broadened by rotation will be the same in all parts corresponding to the component velocities of the inner surface, but will gradually diminish to zero at the edges, at points corresponding to the greatest component velocities of the outer surface.

In this case the intensity at any part of the line is determined by the sectional area of the ring of corresponding and equal component velocity. Thus, in fig. 3 the intensity at the point corre-

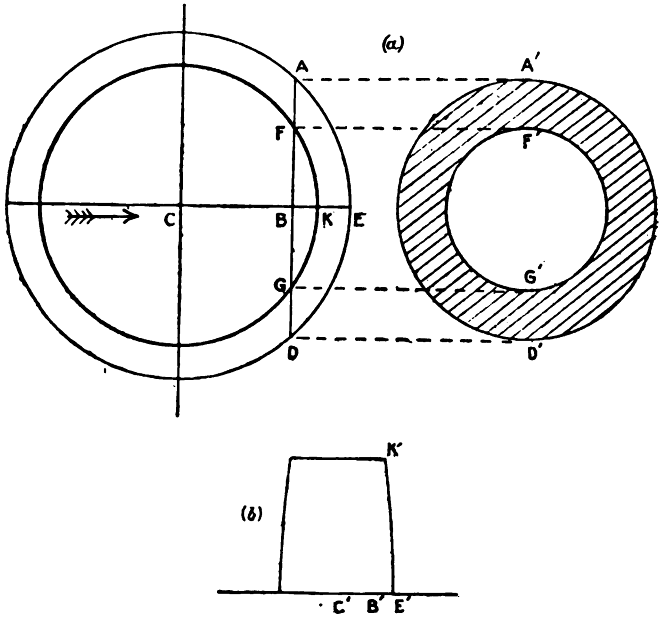


Fig. 3.—Derivation of intensity curve of a bright line produced by a complete shell of vapour, as modified by Rotation.

sponding to the component velocity, CB, is proportional to the area of the circular ring, AFGD. Parallel sections of a hollow sphere have equal areas within the limits of the inner surface, and gradually diminish to the limit of the outer surface. Hence the intensity curve will be of the form shown in fig. 3 *b*.

(9) If the spherical shell of vapour which is assumed to produce a bright line is partly obstructed from view by a central spherical mass, there will be two maxima of intensity in the line when broadened by rotation.

As in previous cases, the points of equal component velocities will lie along circles in planes parallel to the axis of rotation and passing through the Earth, such as ABD in fig. 4 *a*, shown in projection in fig. 4 *b*.

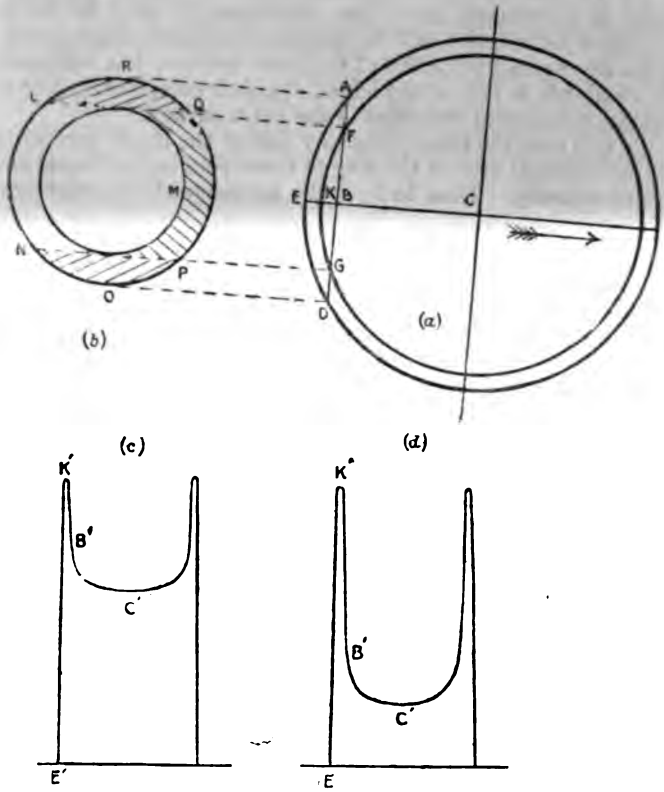


Fig. 4.—Derivation of intensity curves of bright lines, as modified by Rotation.

The intensity of a line at the point corresponding to the velocity, CB, will be proportional to the sectional area, LMNOPR,

if the inner sphere has no effect on the vapour in front of it, and only obstructs the vapour behind.

The part of the line corresponding to the velocity CK will have an intensity proportional to the area of the circular section of the outer sphere at the point K. The resulting intensity curve is shown in fig. 4 *c*, which is drawn to scale for a case in which the radius of the inner surface is one-tenth less than that of the outer.

It is perhaps more nearly approaching the probable conditions in some of the stars to suppose that the vapour lying between us and the central mass is absorbing, so that the bright lines would only be produced by vapours round the limb. In that case the intensity of the part of a line corresponding to a given velocity, CB, would be represented by the combined areas of the segments LRQ and NOP in fig. 4 *b*. The intensity curve derived in this way for the hypothetical case in which the inner radius is one-tenth less than the outer is shown in fig. 4 *d*. It will be seen that in this case the two maxima are much more marked than in the previous one, and a distinct appearance of doubling would probably be observed. This result might be modified if the gas were not completely transparent; but since any absorption by external layers would be effective at all points of the limb, it does not seem likely that the modification would be such as to obliterate the double maximum.

Possible Applications.

In his most recent classification of stellar spectra Professor Pickering has given special prominence to the character of the lines; and from figures which he gives it appears that among stars of the *Sirian* and *Orion* types spectra with diffuse lines are not less numerous than those with sharp lines, while intermediate varieties are also plentiful. Thus, of the spectra included in the first ten of his groups, 71 have lines of ordinary sharpness, 91 have diffuse lines, while 113 are of intermediate character. It does not seem unreasonable to suppose that rotation is the cause of the diffuseness of the lines in many of those spectra where all the lines are affected, though it fails to explain the special broadening of the lines of helium in such a star as ζ *Tauri*. The varying degrees of broadening of the lines in different spectra may be brought about by different surface velocities, or may depend upon the directions of the axes of rotation.

The distribution of intensity in the broadened lines will depend to some extent upon the laws of variation of angular velocity in different stellar latitudes, as already explained.

As regards stars with bright lines, the data at present available are in most cases insufficient to permit an investigation of the presence or absence of rotation effects. In one class of stars, however—those like γ *Cassiopeiæ*—the result of an

examination of the spectra from this point of view is most suggestive. In some of these stars the hydrogen lines are bright and double on a broad dark band, and it has been supposed that they are "double reversals," similar to those of calcium lines in the Sun. Pickering has found that in all cases where the hydrogen lines present this appearance the accompanying dark lines of the spectrum are very wide and feeble. Rapid rotation is therefore suggested by the appearance of the dark lines, and the foregoing investigation suggests that under these circumstances the bright lines would appear double, as we actually see them. There is a possible test as to whether in such stars we really see the effects of rotation—namely, that in stars like δ and μ *Centauri*, which resemble γ *Cassiopeiæ*, except that the dark lines are much less diffuse, the bright lines should either be single or only very closely double, whereas if they are "double reversals" their appearance would seem to be independent of the character of the dark lines. Dr. McClean informs me that his photographs of these spectra do not furnish conclusive evidence on this point, since the dispersion employed was insufficient to exhibit the doubling of the lines in γ *Cassiopeiæ*. It may be added that in γ *Cassiopeiæ* the separation of the components of the double bright lines is five or six times as great as that in the case of the doubly reversed K line in the Sun.

It does not seem improbable, therefore, that some of the points to which attention has been drawn may be found to have a useful bearing on the interpretation of some of the peculiarities which are met with in a survey of stellar spectra.

Inquiry as to the Cause of the Shadow Bands upon the Earth which accompany Total Eclipses of the Sun. By G. Johnstone Stoney, M.A., D.Sc., F.R.S.

If, when the Sun is shining, we look at a shallow pool on the sand of the sea-shore, there is usually a sufficient ripple over the surface of the water to give rise to a very beautiful optical effect. The appearance consists of alternate bands of intense brightness and of shade which seem to travel over the sand at the bottom of the water in harmony with the motion of the waves at the top.

When we consider the cause of this phenomenon, we can see that if there were a second Sun in the heavens so situated that the bright and dark bands it would produce on the sand would coincide with the dark and bright bands of the first Sun, then the two Suns operating together would tend to produce a uniform illumination over the sand, and the appearance of bands would be lost. It is in this way that on a cloudy day, when light arrives from all directions, there is no trace of the banded

appearance. Thus we see that a sufficiently small size of the source of light is a necessary condition for the development of the phenomenon. And, in fact, when we trace the course of the rays refracted by the undulating surface of the water, we find that to produce the most vivid effect the angular size of the luminary must not exceed a certain maximum which depends on the refractive index of water, on the height of the waves, and on the ratio of the depth of the pool to the wave-length.

Now all this is closely analogous to what occurs during an eclipse, when shadow bands are seen swiftly to sweep over the landscape in the neighbourhood of that patch of the Earth upon which, for the time being, the eclipse is total. The umbra of the Moon as it passes down through the Earth's atmosphere is part of so acute a cone that the short portion which traverses the atmosphere is almost a cylinder. It may be likened, as regards the proportion of its length to its thickness, to an ordinary cedar pencil. The lower end of this cylinder reaches the surface of the Earth, and the whole cylinder is carried sideways through the atmosphere with a speed nearly twice the velocity of sound. Within the umbra the temperature of the air falls several degrees, and, as the umbra is hurried along, this low temperature affects different portions of air in succession. The umbra accordingly is, so far as the air is concerned, a cylinder of low temperature travelling sideways through the atmosphere, and surrounded by the penumbra, a larger cylinder, throughout which the reduction of temperature is less. As each situation is reached the low temperature causes condensation of the air and inrush.

The movement consequent upon this in so mobile and compressible a fluid as air will not be simple ; especially where, as in most total eclipses, the section of the umbra is an area of very many square miles. Within the umbra it will consist of complicated alternations of density, but will give rise to more regular undulatory motion in the neighbourhood. The effects will be partly of the nature of forced vibrations owing to the advance of the umbra being swifter than sound, and partly determined by the rate at which waves in air, when once set up, will naturally advance. Under these circumstances we may expect that the air in the neighbourhood of the umbra will be differently affected in front of the advancing cylinder, at its sides, and behind it. In front of the umbra and behind it the effect seems likely to incline towards a state of turmoil, while as the sides are approached it may probably become a more regular undulation. It is here therefore that we should expect the most distinct shadow bands, while in front and in the rear of the umbra the phenomenon will probably assume the form of less regular patches.

Such bands occur because atmospheric waves travelling horizontally and of a length adapted to their elevation over the Earth, must produce alternations of light and shade upon the Earth, provided that the source of light has not too great an

angular size in the direction perpendicular to the bands. Hence it is that the bands are only seen when the arc of uneclipsed Sun has become thin. The intensified effect which can be obtained by reducing the size of the source of light is well seen in the neighbourhood of a naked arc light, which will be found to throw on the ground and surrounding walls a shadow of every considerable discontinuity in the density of the air, such as that over a lighted match.

It is easy to associate this phenomenon with the familiar twinkling of stars, which is due to more rapid and less intense alternations of air density, and therefore requires a still more minute angular size in the source of light. Thus it often happens that even the angular size of a planet has become too large for twinkling at times when fixed stars in the neighbourhood of the planet continue to twinkle perceptibly.

Addendum.

The waves dealt with in the above paper are likely to be of that more rugged type which involves a long series of strong harmonics ; and it seems probable that some of these harmonics will be short enough to produce sound and may be sufficiently intense to be audible. The sound would probably be a rather confused hum like that heard in the neighbourhood of telegraph posts, but with a greater preponderance of the baser tones such as we hear in thunder. It would be interesting, therefore, to listen attentively for an effect of this kind, which if faint would perhaps be most easily heard as a somewhat musical note from stations at a moderate distance to the right and left of the track of totality.

Notes on the Total Eclipse of the Sun, 1900 *May* 28, *observed at Algiers.* By E. W. Maunder and A. C. D. Crommelin.

The watches used in the following time determinations were Usher & Cole 39936, and Isaac 10859, the latter having been kindly lent by the Hydrographer to the Admiralty, and the former by Messrs. Cole. The errors while at Algiers were obtained by comparison with the sidereal clock at the Algiers Observatory, whose errors were kindly communicated by M. Trépied. The longitude of the Observatory is assumed to be $12^m\ 8^s{\cdot}5$ E., the value given in the *Nautical Almanac.* (It may, however, be pointed out that the altitude of the Observatory, 65 feet, given in the *Nautical Almanac* is obviously in error : the correct altitude given by M. Trépied is 342·2 metres, or 1123 feet.) The following are the errors of the two watches on Greenwich Mean Time at the times when comparisons were made :—

G.M. Time of Comparison.		Error of Usher & Cole.	Error of Isaac.
d	h	s	s
1900 May 18	1	2·4 *f*	54·0 *f*
		stopped	
May 22	22	29·5 *f*	39·0 *f*
26	6	36·7 *f*	31·7 *f*
27	6	36·7 *f*	29·2 *f*
28	21½	37·7 *f*	22·3 *f*
June 1	23	...	8·1 *f*
5	0	62·2 *f*	...

The difference between the watches was $10^s{\cdot}4$ on May 28 at $1\frac{1}{2}^h$ and $11^s{\cdot}3$ on May 28 at 5^h.

The adopted errors at the times of first and last contact are :—

d	h	s	s
May 28	3	36·5 *f*	25·6 *f*
	5	36·6 *f*	25·3 *f*

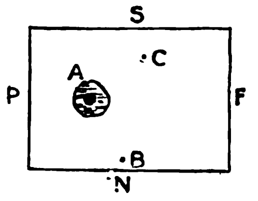
These errors have been applied in the following results, which are thus expressed in G.M.T.

	G.M.T. h m s	Observer.	
1st contact	3 5 14·4	A.C.	Probably at least 5 seconds late.
2nd „	4 17 17·1	M.	
3rd „	4 18 19·5	Various	
4th „	5 22 19·7	A.C.	

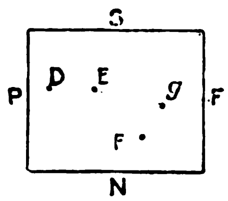
An independent determination by Rev. C. D. P. Davies gave $5^h\ 22^m\ 17^s{\cdot}5$ for fourth contact.

Neither M. nor A.C. observed the third contact directly, but various members of the party made the duration of totality $62^s{\cdot}4$ or thereabouts, which has been applied to the observed time of second contact.

There were two spot groups on the Sun, and the times of disappearance of some of the spots were noted. The accompanying rough sketches will probably suffice for the identification of the spots observed.



First Group.



Second Group.

		h	m	s	
Disappearance of preceding edge of penumbra of A		3	29	7	G.M.T.
" " " " umbra	"	3	29	22	
" " following " penumbra	"	3	29	45	
" " D	...	3	49	30	
" " F	...	3	52	5	

The place of observation was 696 feet west and 411 feet south of the Algiers Lighthouse, whose coordinates are $12^{m}\ 17^{s}\cdot0$ E., $36^\circ\ 47'\ 16''$ N. Our altitude was about 120 feet.

The duration of totality was about five seconds shorter than that calculated from the *Nautical Almanac* data, and about one second shorter than that calculated from the data of the American Ephemeris. The experience of this eclipse, combined with that of the Indian eclipse of 1898, would appear to establish the superiority of the constants used by the American Ephemeris. Both ephemerides use the same semi-diameter for the Sun, but the American value for the semi-diameter of the Moon is smaller by $0''\cdot9$ than that of the *Nautical Almanac.*

Remarks on the Total Eclipse of the Sun, 1900 *May* 28, *observed at Navalmoral* (*Spain*). By Rev. S. J. Johnson.

I observed from the top of a hill a mile south of Navalmoral Station. The first nip of limbs at 2.35 (Madrid mean time) was clear and sharp. When the Sun was half obscured, thermometer three feet above the ground stood at 88°. A large portion of the Moon's limb was now visible outside the Sun, quite 3′ of arc in extent. At 3.27, when the magnitude of the eclipse reached the maximum at Greenwich, the light began to wane and became livid and unnatural. Thermometer then 84°. When eleven digits of the Sun were obscured it had gone down to 80°. Just after totality it registered 79°. In twenty-three minutes it had recovered 1° only.

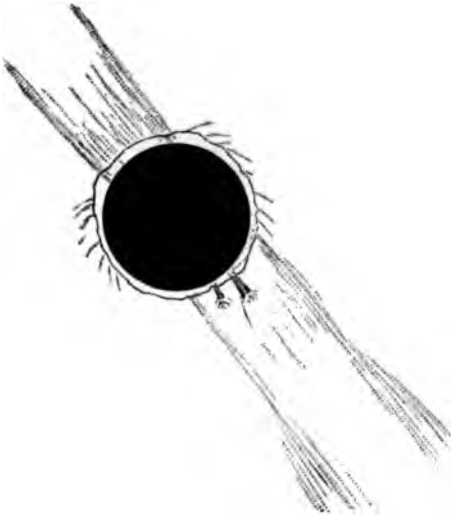
The inner corona was bright round a large portion of the Sun more than five seconds before totality, but I cannot say that I noticed it after the total phase was over.

Equatorial streamers developed to the extent of two solar diameters on the western limb and of one on the eastern. They could, of course, be faintly traced further. Two feathery prominences, very conspicuous in the 2-inch telescope I was using, at the lower limb, one $1\frac{1}{2}'$ in extent, the other 1′—white, tinted with red.

The two really striking points were—

1. The scarlet sierra, or rim of brilliant red, stretching along the limb for about 150°. This was visible for eight or ten seconds

only, just before the Sun reappeared. I attribute the unusual extent of this to the fact that the Moon only just overlapped the Sun, the difference of diameters being small. (See Professor Grant's paper on this in *Monthly Notices*, 1872.)



2. The exquisite rosy glow displayed by a small bank of clouds on the S.W. horizon. Perhaps this gorgeous illumination was a reflection from the redness on the Sun just mentioned.

Totality lasted exactly eighty seconds.

Mercury flashed out brilliantly the instant the Sun was covered. I looked in vain for *Aldebaran*. My son made out *Castor* and *Pollux* with an opera-glass of wide field.

The equatorial streamers were of a pale white colour. The recovery of light was marvellously rapid. Being close to a stone building we looked for shadow bands, but none were seen.

Venus very bright at 3.27; no doubt could have been seen many minutes before this. It was visible easily for twenty-three minutes after totality.

The sky darkened more uniformly than I expected. I noticed none of the dark purple patches that I remember in the merely partial eclipse of 1870 in the south of England about the time of greatest obscuration. I was able to see the seconds hands of the watch without artificial light.

While we were experiencing considerable heat at Navalmoral, some ten or twelve miles to the north lay a range of snow-capped mountains.

Melplash Vicarage, Bridport: June 5.

The Partial Eclipse of the Sun, 1900 May 28, observed at the Stonyhurst College Observatory. By the Rev. W. Sidgreaves, S.J.

The continuous cloud of the morning began to break about noon. But there was no opportunity of observing the chromosphere for comparison with the photographs of the total eclipse until close upon the time of first contact. The examination was then carried on under the disadvantage of frequent passing clouds and mist. Four small prominences were located at the following position angles, measured from the north point round by east.

1 prominence	13″·1	high at	39°	25′
2	"	15·25	"	57	20
3	"	13·1	"	61	45
4	"	10·9	"	160	0

The arc 270° ~ 332° escaped observation, being covered by the Moon at the time.

At times the sky was very clear, and definition perfect. The cusps were seen by three observers to be quite sharp, and the Moon's limb was a smooth arc, except for four small lunar mountains projected on the solar disc. No trace of the dark Moon could be seen outside the cusps. The boiling appearance at the Moon's limb did not seem to differ at all from that of the Sun's limb.

The solar radiation thermometer was read at intervals of ten minutes during the eclipse, and the readings being maxima are each the highest during the preceding ten minutes.

G.M.T. h m	Fah. Scale. °	G.M.T. h m	Fah. Scale. °
2 50	120·8	4 0	84·1
3 0	115·0	10	89·2
10	112·5	20	93·9
20	101·2	30	92·0
30	95·8	40	109·5
40	90·5	50	114·8
50	85·2		

The last contact was timed by two observers: one with the 5-inch Clark Equatorial mounted in open air, the other with the 4-inch Cooke finder on the large equatorial. The times were taken directly from the sidereal clock in the transit room by two assistants, each receiving his electrical signal from his observer at the telescope. The night was cloudless, and the errors of the transit instrument were secured with sufficient accuracy. The

clock's rate, losing 3·5 secs. daily, rests upon a single star observed on the 24th, and a pair on the 29th compared with seven clock-stars observed on the 28th. The mean rate between 24th and 28th was 3·3 secs., and 3·8 secs. between 28th and 29th. The resulting sidereal time of last contact was:

		h	m	s
By the 5-inch Clark ...	...	9	5	8·3
„ „ 4-inch Cooke ...	...	9	5	8·4

The sky was very clear at the time, and definition excellent.

Observations of the Partial Eclipse of the Sun, 1900 *May* 28, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

Owing to the prevalence of cloud, the first contact could not be seen; but toward the end of the eclipse the sky cleared, and satisfactory observations of the last contact were secured.

An interval of clear sky occurred just before the transit of the Moon's limb over the more prominent of two groups of sun-spots, and times of contact with the umbra of the largest of the group were observed.

In order to determine approximately the time of "greatest phase" the relative distances of the limbs of the Sun and Moon were recorded during intervals of clear sky. The resulting time is $3^h\ 53^m\ 20^s$ G.M.T.

The following are the observations of sun-spot and last contact:—

'henomenon.	Observer.	Telescope.	Aperture.	Power.	G.M.T.	Remarks.
-spot.			in.		h m s	
'irst contact with umbra	R.	Heliometer	7·5	80	3 12 51	
ast contact	R.	„	„	„	3 13 3	Thought I saw it again some seconds after this time. Very diffused; cloud passing.
of Eclipse.						
ast contact	W.	Barclay	10	90	4 56 35·4	Very good; last trace had just vanished. Recorded on Chronograph.
„ „	R.	Heliometer	7·5	80	4 56 32·7	Good, but suspected trace of contact 1ˢ later. Observed by projection on a screen.
„ „	C.	Marlborough	3·2	72	4 56 34·2	Instrument shaken by wind.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; C., Mr. E. E. McClellan.

adcliffe Observatory: 1900 *June* 7.

The Partial Eclipse of the Sun, 1900 *May* 28, *observed at Armagh.* By J. L. E. Dreyer, Ph.D.

At Armagh passing clouds were frequently obscuring the Sun during the greater part of the day, and the first contact was therefore not seen here. The last contact was very satisfactorily observed with the 10-inch refractor. It occurred at $4^h\ 49^m\ 46^s{\cdot}2$ G.M.T.

Armagh Observatory: 1900 *June* 7.

The Partial Eclipse of the Sun, 1900 *May* 28, *observed at Forest Lodge, Maresfield, Sussex.* By Capt. W. Noble.

At the predicted time of first contact the sky was covered with a dense pall of black cumulus, and it was not until at least a quarter of an hour later that the first glimpse of the Sun was obtained. By that time, of course, the Moon had advanced very perceptibly on to his disc. At the time of greatest obscuration it was very instructive to note how much larger the crescent of the Sun appeared (owing to irradiation) as projected upon a sheet of cardboard than it did as viewed through a densely smoked glass. As the eclipse advanced the sky cleared, and the latter part of the phenomenon was observed in a brilliant area of sky. The smoothness of the Moon's limb was very notable. In all the (pretty numerous) eclipses I have observed I have never seen it so curiously free from irregularity. No trace of a lunar atmosphere was detectable at the cusps, nor could the Moon's limb be traced in the smallest degree beyond the Sun, although I have formerly succeeded in seeing it to the extent of $4''$ or $5''$ outside of the solar limb. The last contact was well observed at $9^h\ 21^m\ 38^s$ local sidereal time $= 4^h\ 58^m\ 14^s{\cdot}85$ G.M.T. The power employed was 74, with a diagonal eyepiece, on my 4·2-inch Ross Equatorial. The latitude of my observatory is $51°\ 0'\ 59''{\cdot}8$ N. and its longitude $17^s{\cdot}11$ E. of Greenwich.

Forest Lodge: 1900 *June* 7.

The Partial Eclipse of the Sun, 1900 May 28, observed at Norwich. By G. J. Newbegin.

The meteorological conditions in and around Norwich were much better than we were led to expect as the afternoon began. First contact was not visible by reason of clouds, but these soon separated more and more, until that which did look nearly hopeless became quite a success, what cloud there was being rather useful than otherwise in making naked-eye observations.

The Sun's cusps appeared very sharply cut out by the Moon, and the minutes before and after maximum revealed a great decrease of light as one had opportunity to glance at the landscape: a feeble watery light, such as we see sometimes in the shorter days when we look at the Sun through much vapour. *Venus* was noticeable at the maximum, but no other stars.

I was able to expose a series of plates which I think will prove to be a fairly regular sequence of the eclipse as seen here. The first is very faint indeed, because of cloud, my impatience to get something brooking no further delay. The exposure in all cases was $\frac{1}{100}$ sec.

Times of Exposure.

No.	G.M.T. h	m	s	No.	G.M.T. h	m	s
2	3	0	57	14	4	5	53
4	3	6	24	16	4	14	3
6	3	19	3	18	4	24	53
8	3	34	51	20	4	34	4
10	3	45	36	2	4	46	29
12	3	55	5	24	4	54	0

The eclipse ended at $4^h\ 55^m\ 5^s$ as watched by my eye on the camera focus-plate, the eye seeming still to hold the Moon after contact had ceased, the time I have mentioned being that at which I last saw her. My son noted the time in all cases above mentioned, either as I spoke or clicked the shutter of the camera.

Observations of Capella as a Double Star made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Mr. Newall having called attention to the possibility of securing micrometric measures of the spectroscopic binary *Capella*, Mr. Dyson and Mr. Lewis examined it with the 28-inch refractor on April 4. Both observers agreed that the star was

elongated. Various coloured shades and eyepieces were us The elongation appeared to be quite 0″·1.

It was afterwards observed on every available night several observers, care being taken that the observers should unbiassed as far as possible. The observation is naturally of very delicate kind, and large discordances are to be expecte but the change of position angle observed through a large arc the orbit agrees on the whole well with the calculated chang taking the period as 104 days. With two exceptions the obse vations were made on the west of the meridian.

The following are the individual measures, with the ho angle at which they were made :—

	d	h		°	′	Hour angle. h
April	4	9	Mr. Dyson	307	0	5 W.
			„ Lewis	286	38	5
	15	7	„ Brookes	264	30	3½
		7½	„ Dyson	263	30	4
		8	„ Lewis	256	5	4½
	16	8	„ Dyson	269	0	4½
		8	„ Bowyer	251	20	4½
	19	9½	„ Lewis	255	22	6
		9½	„ Bowyer	240	20	6
	20	8	„ Melotte	235	33	5
		8¼	„ Furner	241	3	5¼
		8½	„ Dyson	242	20	5½
		8½	„ Lewis	237	22	5½
		8¾	„ Bowyer	236	40	5¾
	23	8	„ Lewis	245	27	5
	24	8¼	„ Bryant	226	16	5¼
	25	8	„ Bowyer	232	45	5
			„ Furner	233	29	5
	26	8	„ Lewis	240	38	5
		8½	„ Bartlett	235	10	5½
		8¾	„ Hollis	227	0	6 W.
	28	noon	„ Bryant	206	58	3 E.
May	1	7½	„ Bryant	197	16	5 W.
	2	8	„ Lewis	229	10	5½
		8½	„ Bartlett	230	0	6
	3	7½	„ Bowyer	229	37	5
	7	8¼	„ Bowyer	219	10	6
	10	8¼	„ Bowyer	216	45	6¼
			„ Furner	219	59	6¼
	11	7¾	„ Bowyer	216	0	5¾
	17	5	„ Bryant	139	0	3½
	29	7½	„ Bryant	95	20	6½ W.

Royal Observatory, Greenwich:
1900 *June* 8.

[Further observations made since June 8.]

June 19	19	Mr. Bryant	14	0	4¼ E.
20	2¾	„ Bryant	20	47	3½ W.
	3¼	„ Furner	20	45	4
	3¾	„ Witchell	20	15	4½]

Note on a Meteoric Shower south of Corvus. By W. F. Denning.

In the region between *Corvus* and *Centaurus* there appears to be a well-defined radiant point of meteors at the April epoch. While watching for the *Lyrids* in 1898 April 12–23, Professor A. S. Herschel at Slough recorded about ten slow-moving meteors directed from a centre at 189°–27°, 5° S. of *β Corvi.* Two of the meteors were seen at other stations (Leicester and Bristol), and their real paths were computed. In April of the present year a few more of the *Corvids* appeared, and one of them visible on April 21 at 10^h 31^m was registered at three stations, viz. Slough, Wallingford, and Leicester. The heights, &c., of the several objects observed in 1898 and 1900 were as under :—

Date.	Time.	Mag.	Height at first.	Height at last.	Path.	Velocity.	Radiant.
1898.	h m		Miles.	Miles.	Miles.	Miles.	° °
April 16	10 48	1	60	48	91	24	189 – 31
17	10 28	4	72	70	34	23	176 – 35*
1900. April 21	10 31	3	60	54	50	17	188 – 32

Radiants in nearly the same position appear to have been previously determined as follow :—

1869. Jan. 21–Feb. 23	188° – 26°	8 meteors. Derived by W. F. D. from Tupman's observations in the Mediterranean.
1858-63. March	192 – 38	Heis. Derived from Neumayer's observations at Melbourne.
April	194 – 30	

The first observation of the shower seems therefore to have been about forty years ago, and it must be regarded as forming a strong display in recent times, or it would never have attracted attention at places in the northern hemisphere where the altitude of the radiant when on the meridian is less than 10°.

In various years since 1873 I have noted a few of these April

* This position is probably quite 10° west of the correct centre, and may represent a different shower.

Corvi-Centaurids, and from a projection of the observations find the radiant in 187°–33°. There are several other showers not far distant from this point.

From the whole of the observations the mean place of the radiant would seem to be in 189°–31½°. At Greenwich on April 21 this point is due S. alt. 7° at about 10^h 40^m P.M. It is to be hoped that observers in Australia, at the Cape, and other southern stations will endeavour to re-detect this stream at future returns of the April *Lyrids*. There are also some well-defined showers in April from *Libra* at 206°–9°, 217°–9°, 226°–5°, and 235°–14°. In May and June there is a prominent display of *Scorpiids* (253°–22°), in June of *Sagittarids* (269°–23°), and at the end of July of *Piscis Australids* (339°–30°) and *Aquarids* (340°–12°). Contemporary with the August *Perseids* there is a strong display of *Capricornids* from 304°–13° (near *α Capricorni*). These several streams have been pretty successfully observed in England, but they might be seen to greater advantage in the southern hemisphere.

Bishopston, Bristol: 1900 *May* 20.

Erratum in Mr. Ellis's paper, Vol. LX., page 151, *line* 4, *for* March 20 *read* March 30.

MONTHLY NOTICES

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A Possible Explanation of the Sun-spot Period.

By Ernest W. Brown, D.Sc., F.R.S.

This paper is an attempt to obtain a gravitational cause for the Sun-spot period on somewhat different lines from those which have hitherto been followed.*

The possibility that the period is in some way connected with the positions of the planets has been frequently suggested. Carrington, in his well known work, has given a comparison of the curve formed from the Sun-spot numbers with one having the same period as that of *Jupiter* round the Sun. Balfour Stewart (*Trans. R. S. Edin.*, vol. xxiii.) examined the influence of *Jupiter* and the inner planets. Birkeland (*Vidensk. Skrifter*, 1899, Christiania) has done a similar piece of work on a much more extended scale. These investigations all appear to have produced a negative result as far as the main period is concerned, the chief reason being that the only long-period planet considered, *i.e. Jupiter*, has a period of 11·86 years, so that the examination ultimately reduces to an attempt to make the *Jupiter* curve agree with the Sun-spot curve. It will be seen below that the main difference of the method followed here from that of previous investigators, is the inclusion of an action due to *Saturn* combined with that of *Jupiter*, with possible minor effects due to the inner planets, instead of considering *Jupiter* and the inner planets only. If we compound two periodic curves of nearly equal amplitudes and

* Part of the paper has been re-written since it was first presented to the Society, owing to the valuable criticisms of the referees. My attention was also called by them to the memoir of M. Birkeland, which has appeared during the present year.

periods not very different, an *apparent* period may result different from the component periods when the series does not extend over a very great number of maxima.

If we examine the tide-raising forces on the Sun due to the planets, we obtain the following relative numbers :—

By *Mercury*	8·6	By *Jupiter*	2·24
„ *Venus*	2·06	„ *Saturn*	·11
„ The Earth	1·00	„ *Uranus*	·002
„ *Mars*	·03	„ *Neptune*	·0006

The mean values of the distances of the planets are used, taking the mean distance and mass of the Earth as units. The mass of *Mercury* is assumed to be $\frac{1}{20}$ that of the Earth ; any probable change in this value will not affect the argument of this paper.

It is at once seen that the inner planets, with the exception of *Mars*, all produce considerable relative effects, but as their periods are very short, it will be assumed that they can be neglected in the search for long-period effects. As *Uranus* and *Neptune* can hardly be supposed, from the numbers given above, to have any influence, *Jupiter* and *Saturn* alone remain.

Now *Jupiter* alone, if we neglect the eccentricity of its orbit, cannot in general produce any long-period term, for the period of rotation of the Sun is about twenty-five days, and the wave produced by *Jupiter* travels round the Sun, relatively to the Sun's surface, in very nearly the same period. The eccentricity of the orbit of *Jupiter* is however about $\frac{1}{20}$, and the tide-raising force, 2·24, due to *Jupiter*, will vary by $\pm$·33 as the planet moves in its orbit. This may be considered as a wave superposed on the main *Jupiter* wave, and its period will be that of *Jupiter*, since the motion of the perihelion can be neglected.

Again, *Saturn*, in its motion round the Sun, raises a wave with a force of magnitude ·11. Whenever this wave crosses the main *Jupiter* wave, the latter will have its height increased, and there will be a corresponding diminution when the waves are in quadrature with one another. The period of the wave relative to the main *Jupiter* wave will be that of *Saturn* relative to *Jupiter* round the Sun, that is, 19·86 years. But as a tide-raising force produces equal waves on opposite sides of the Sun, the intervals between coincidences will be just half of this, that is 9·93 years.

Hence the main *Jupiter* wave is periodically altered by two causes :—

	Period.	Mag. of force.
By Jupiter's eccentricity	11·86 years	·33
By the motion of Saturn	9·93 „	·11

The two forces are in the ratio 3 : 1, but these numbers cannot contribute anything to the argument further than that they are of the same order of magnitude, even if that is necessary. For

ompar

the question under consideration is not the periodic change in the wave height, but a phenomenon here supposed to be due to this change: namely, increase of activity on the Sun's surface due to the relative positions of the waves which in reality form long-period "spring" tides. The periods are the only quantities which admit of more or less exact numerical calculation.

Now, the period of activity of the solar surface has generally been estimated at 11·1 years, and as the number of maxima from which it is deduced is not very large, it might easily have been arrived at even if the actual curves be really compounded from two of not very different amplitudes. It must be remembered also that the period is only an average one; the distances between the various maxima actually range from about 8 to 18 years, so that even if a principal cause with a period of 11·1 years had been found, the deviations would have been considerable.

In the course of the 150 years during which numerical estimates of the activity are available, there is some evidence of a much longer periodic change which appears to run from one maximum to the next in about sixty years. This can be shown to be a direct consequence of the two periods. For

$$5 \times 11{\cdot}86 = 59{\cdot}3,$$
$$6 \times 9{\cdot}93 = 59{\cdot}6,$$

the exact period between two coincidences of phase being

$$1 \div \left(\frac{1}{9{\cdot}93} - \frac{1}{11{\cdot}86}\right) = 61 \text{ years.}$$

Thus every 61 years the two waves are in approximately the same positions relatively to the main *Jupiter* wave, and a corresponding change in the Sun-spot cycle may be expected.

A curve (plate 20) has been drawn, showing the effect of the combination of two periodic terms of periods, 11·86 and 9·93 years respectively. In order to simplify the drawing as much as possible, only the maxima and minima of these were plotted, and they were then joined by (thin) straight lines. The minima were placed at equal distances from the maxima, although a more exact agreement might perhaps have been obtained by making the distance from maximum to minimum longer than that from minimum to maximum. The amplitudes must, from the nature of the case, be somewhat arbitrary, judging from the numerical analysis given later on. They were taken in the ratio of 7 : 5, the larger amplitude being used for the *Jupiter* period. The maxima are placed below and the minima above. The heavy line shows the effect of compounding the two curves.

The lower curve represents Wolf's Sun-spot numbers. In the period before 1750—the dotted portion—the magnitudes are not known; the maxima have therefore been drawn with equal ordinates. For the period since 1750, the Sun-spot curves are

plotted from the annual means given by Wolf.* Thus a period of about 290 years is available for comparison.

In the period before 1750, represented on the upper part of the plate, one must regard Wolf's results with considerable doubt. No connected series of observations were then available. A maximum was sometimes inferred from the mention of a big spot on the Sun easily visible to the naked eye; such a spot has occurred during the minimum now in progress, and therefore one can hardly regard the deduction of a maximum from a big spot as very trustworthy. In fact Wolfer, in rediscussing Wolf's results, gets in one part two maxima and one minimum where Wolf had found only one maximum. Again, it is not easy to decide on what principle (*e.g.* by the number of spots visible in a given time, or by the spotted area) the Sun-spot curves should be formed. The hump which is visible in several cases on the descending slope may possibly come out as the real maximum by another method of reckoning. In fact, the curve gives an appearance of definiteness which disappears when the observations are more closely examined. A reference to the plate attached to Mr. Ellis's paper in the *Monthly Notices* for last December will illustrate this last point; the Sun-spot curves are there drawn on a larger scale from the monthly instead of the annual means.

On comparing the theoretical and observed curves, it will be seen—

(*a*) That the maxima agree on the whole fairly well, and better in the later than in the earlier times.

(*b*) That from 1750–1898 there are three minima and two maxima of the 61-year period which agree fairly well with those of the Sun-spot curve.

(*c*) That at all the maxima of the 61-year period there is an almost exact coincidence of the theoretical and observed maxima.

(*d*) That the deviations from coincidence of the maxima generally occur where they might be expected to occur—namely, round the minima of the 61-year period. This is, in particular, the case before 1750.

(*e*) That the principal deviations are the maxima of dates 1615, 1675, 1894; the deviations of dates 1626, 1685, 1750, 1761 being near the minima of the 61-year period. The first two exceptions are probably due to errors in assigning the dates to these maxima of the Sun-spot curves. Wolf says that there is a probable error of about two years in the date of each maximum before 1750; an error of four years in each of these cases is not improbable. The supposition of error is strengthened by the fact that the slope from maximum to minimum is greater

* Wolf's results have been summarised by A. Wolfer in the *Meteorologische Zeitschrift* for June 1892. The results up to 1891, used here, have been obtained from this paper; for the period 1891–8 the numbers were extracted from Wolfer's annual reports.

than that from minimum to maximum—contrary to what happens with the great majority of the 11·1-year periods.

The deviation of the maximum apparently occurring about 1894 is not so easily explained away, as it is in a period when doubt cannot be cast on the observations. In fact, it appears to coincide more nearly with the theoretical minimum than with the maximum. A general shift back of the theoretical curve will not improve matters. The explanation would probably be that there are other causes tending to displace the position of the actual maximum. The prolonged minimum now in progress seems to confirm this. If the theory developed here is correct, the actual minimum should not be reached until 1901 or 1902, if it is attained as early. The next maximum should be a period of great activity, as it will fall on a maximum of the 61-year period, and it should be attained about 1908. The time-distance from the previous maximum would be about 14 years—an event which is not unusual, as a reference to the plate will show.

The rise of the curve about 1870 is seen by a reference to the monthly means to be due to a very large disturbance lasting a comparatively short time.

(*f*) That the maxima of disturbance do not coincide with the positions of conjunction or opposition of *Saturn* and *Jupiter*. These planets were in conjunction and *Jupiter* was at aphelion in 1827, a date about ten years from the minimum of the 61-year period.

A closer agreement between the two curves can hardly be expected, in view of the many arbitrary quantities which enter into their formation. In addition, the actions of *Mercury*, *Venus*, and the Earth may produce effects comparable with those produced by *Jupiter* and *Saturn*; they might well cause considerable deviations of the maxima at any one period, and their effects would only be eliminated by an analysis of the observations extending over a considerable period of time. It therefore seems advisable to examine the numbers, and to see what evidence of the existence of the periods the observations afford.

For this purpose the mean annual values of the Sun-spot numbers given by Wolf were used. The period 1761–1880 is the longest complete cycle which is available; this includes 12 maxima of the 9·93-year period, and 10 of the 11·86-year period. Arranging these in groups of 10, for the former period we obtain the following mean values :—

1	2	3	4	5	6	7	8	9	10
57	47	34	30	27	38	54	65	67	64

The numbers 1, 2 . . . are the parts of a period, and the mean under each is derived from twelve annual means, each of the latter being derived from the twelve monthly numbers

given by Wolf. Although the period is rather less than ten years, the difference is not sufficient to have any material effect in the course of 120 years. These ten means are plotted in fig. 1, the numbers at the side corresponding to Wolf's Sun-spot numbers, and those below corresponding to the above ten parts of a period.

9·93-year Period.

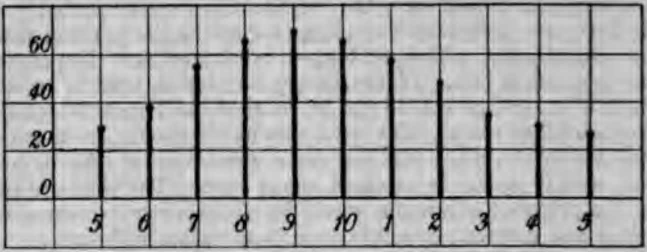


FIG. 1.

Next, to test the 11·86-year period, the same numbers were arranged in groups of twelve. Owing to the fact that 120 years is rather more than ten periods, to save trouble the device adopted in the reduction of tidal observations was used —an extra number, the mean of those immediately preceding and following, was inserted in the middle of the series, which thus extends over 119 years. The resulting twelve means, each formed from ten annual means, are as follows :—

1	2	3	4	5	6	7	8	9	10	11	12
25	33	47	57	73	72	65	60	55	43	29	20

As before, the numbers 1, 2 . . . 12 are parts of a period; the values have been plotted in fig. 2.

11·86-year Period.

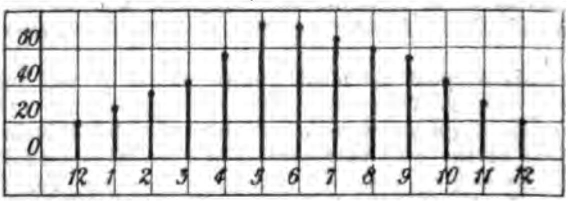


FIG. 2.

In each case the differences from the value of the mean, 48, seem to justify an assertion as to the existence of the periods.

An attempt was next made to see if any of the other periods were to be found in the Sun-spot numbers. The following are those which seemed most likely to be shown on account of the magnitudes of the forces :—

Mercury, effect of eccentricity, ·24085 year.

M—V, ·19795 year,	V—J, ·32242 year,
M—E, ·15863 „	E—J, ·54603 „
M—J, ·12292 „	V—E, ·79936 „

where M, V, E, J, denote *Mercury*, *Venus*, the Earth, and *Jupiter*, respectively, and M—V, M—E, . . . , the halves of their relative periods. The halves of all the periods, except that due to the eccentricity of *Mercury*, must be used owing to the fact that two equal waves are raised on opposite sides of the Sun, and we are only concerned here with the coincidences of these waves. All of these periods are short, and it is very doubtful whether the observations can be taken with sufficient accuracy to test any of them. However, an attempt was made with the longest, V—E, which has a period of almost exactly four-fifths of a year. In the course of sixty years the deviation from an exact period of four-fifths would be less than a fortnight. I therefore took Wolf's monthly means from 1831–1890, which is almost exactly a long-period cycle, and arranged them in 48 columns corresponding to the 48 months in a four-year period. These 48 means, each formed from 15 numbers, should give 5 maxima and 5 minima if the action of V—E is to be shown. The means are given in the following table :—

Month Year.	1	2	3	4	5	6	7	8	9	10	11	12
1	42·3	46·5	50·4	47·4	44·3	41·9	43·3	54·7	52·7	57·6	53·2	47·9
2	54·5	57·3	55·6	52·3	51·7	52·2	53·2	51·7	50·2	55·4	52·2	59·4
3	54·9	58·1	51·5	51·7	51·2	54·7	51·3	49·5	46·0	43·9	43·1	48·1
4	43·8	46·9	53·7	49·2	50·9	45·3	44·1	43·7	51·3	46·8	45·3	40·9

Plotting these as before, we obtain the curve in fig. 3, where the numbers 18, 22 . . . show the ordinates which correspond to year 2, month 6; year 2, month 10, etc., in the above table.

4-year Period.

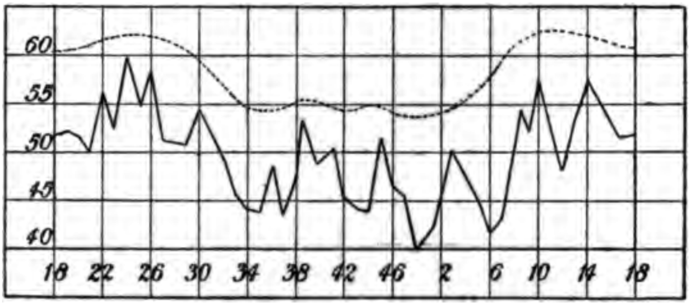


Fig. 3.

The four-year period which appears to result from this curve is illusory. If a succession of 12-year periods be plotted in groups of four years, the maxima will all fall in one place; thus the apparent four year period is due to the 11·86-year period. Similarly, the apparent approximate symmetry about the centre of the curve in fig. 4, as shown by the dotted line, is due to the 9·93-year period; an even number of such periods arranged in groups of 4 years will give an approximately symmetrical curve.

As we are searching for a $\frac{4}{5}$-year period, the numbers in the table should contain five periods. Dividing each period into nine equal parts and estimating their magnitudes from fig. 4,* we obtain the following series of means for the nine parts of the period:—

1	2	3	4	5	6	7	8	9
50·7	49·9	51·0	50·0	48·5	49·0	49·6	49·4	49·9

which are plotted in fig. 4.

·7994-year Period.

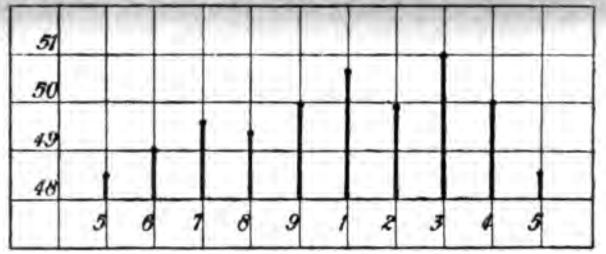


Fig. 4.

Although each of the nine means arises from about 80 monthly means, and although their general change seems to afford some evidence of the required period, the differences from their mean value are too small to give more than a doubtful indication of the existence of the period.

1900 Aug. 4.

* They were actually estimated from a large-scale figure.

Note on the Formulæ for Star Corrections. By P. H. Cowell, M.A.

The following method of obtaining the formulæ used in star corrections appears to me simpler than that usually given in text books.

(i.) Precession and Nutation.

Some rotation will bring the pole and equinox of date into coincidence with the mean pole and equinox for the beginning of the year. Let this rotation be resolved into components :

D round the first point of *Aries* ;
C round the pole of the prime celestial meridian ;
f round the pole of the equator.

D, C, f are therefore day-numbers independent of the particular star.

Then for a particular star, whose R.A. and declination are a and δ, the rotation may be farther resolved into

$C \sin a + D \cos a$ about the projection of the direction of the star upon the equator ;
$C \cos a - D \sin a$ about the pole of the meridian through the star ;
f about the pole of the equator.

The geometrical effects of these last-named rotations are

$(C \sin a + D \cos a)\ \frac{1}{15} \tan \delta$	in R.A.
$C \cos a - D \sin a$	in Decl.
f	in R.A.

(ii.) Aberration.

The effect of aberration is the same as that of a displacement of the observer. This displacement may be resolved into components :

B towards the first point of *Aries* ;
A towards the pole of the prime celestial meridian ;
i towards the pole of the equator.

B, A, i are therefore day-numbers independent of the particular star.

Then for a particular star the displacement may be further resolved into

$A \sin a + B \cos a$ along the projection of the direction of the star upon the equator;
$A \cos a - B \sin a$ at right angles to the meridian of the star ;
i towards the pole of the equator.

The geometrical effects of these displacements are

$$\begin{array}{ll} -(A \sin\alpha + B\cos\alpha)\sin\delta & \text{in declination;} \\ (A\cos\alpha - B\sin\alpha)\frac{1}{15}\sec\delta & \text{in R.A.;} \\ i\ \cos\delta & \text{in declination.} \end{array}$$

Combining the two results, and reversing the signs of some of the day-numbers, we have the well-known formulæ :

Apparent R.A.—Mean R.A.

$$= A\,\tfrac{1}{15}\cos\alpha\sec\delta + B\,\tfrac{1}{15}\sin\alpha\sec\delta$$
$$+ C\,\tfrac{1}{15}\sin\alpha\tan\delta + D\,\tfrac{1}{15}\cos\alpha\tan\delta + f.$$

Apparent Declination—Mean Declination.

$$= -A\sin\alpha\sin\delta + B\cos\alpha\sin\delta$$
$$+ C\cos\alpha \quad - D\sin\alpha + i\cos\delta$$

where it should be observed that C has a slightly different meaning to that assigned to it in the *Nautical Almanac* (see Turner's Star Correction Tables).

This method of treatment assigns geometrical meanings to the day-numbers, and from their geometrical meaning some of their numerical properties are easily recalled ; for instance :

D is the nutation in obliquity, and its principal term has a nineteen-year period ;

C, f are components of the precession and nutation in longitude. As these are together equivalent to a rotation about the pole of the ecliptic (except for the minute planetary precession), it follows that $C = f\tan\epsilon$, nearly, when ϵ is the obliquity of the ecliptic, or $C = \frac{2}{5}f$, nearly.

Moreover C, f alone of the day-numbers change suddenly at the turn of the year, and contain a term proportional to the fraction of the year. The principal parts of the remainders of C and f, and the principal part of D, are of nineteen years' period, and depend, as is well known, on the fact that the lunar precession is equivalent to a rotation round the pole of the Moon's orbit, which revolves in nineteen years round the pole of the ecliptic.

A, B, i are components of a vector the extremity of which describes the hodograph of the Earth's orbit. This hodograph is a circle ; the vector represented by A, B, f, is not drawn from the origin but from the centre of the circle. The Earth's velocity is the resultant of two components, one of which is a constant, and produces an aberration whose value for stars 90° distant from its apex is $\frac{1}{3}''$, while the other component is constant in magnitude and at right angles to the Earth's radius vector. It is perhaps not familiar to everyone that, when an apparent place is corrected for aberration by the ordinary formulæ, the mean place is not that in which the star would appear were the Earth at

rest, or the velocity of light infinite, but it remains affected by the aberration due to a velocity parallel to the minor axis of the Earth's orbit.

A, i have a resultant in the plane of the ecliptic, and therefore $i = \frac{2}{5}$ A, nearly ; also A, i vanish at the solstices, while B vanishes at the equinoxes.

In connection with the uncorrected portion of the aberration, it may be further remarked that a planet is completely corrected for aberration by antedating the observation, so that there is a discordance of $\frac{1}{3}''$ in the method of treating the two classes of bodies.

Partial Eclipse of the Sun, 1900 *May* 28, *observed at Col. Cooper's Observatory, Markree.* By F. W. Henkel, B.A.

The weather being very fine here, the progress of the eclipse was watched under favourable circumstances.

The maximum obscuration was at about 3.45 P.M. G.M.T., and magnitude of eclipse ·7.

The last contact took place at $4^h\ 49^m\ 25^s$ G.M.T. There was a slight falling off of light observable during the time of greatest obscuration.

The sunshine record for this date gives a graphic picture of the eclipse (or rather the uneclipsed portion of the Sun), shown by the narrowing down of the trace and its subsequent widening again during the progress of the phenomenon. The Merz "Comet Seeker," with dark glasses, was the instrument used to watch the eclipse.

Discovery and Observations of Comet Brooks (*b* 1900). By W. R. Brooks, M.A., D.Sc.

While engaged in sweeping the eastern heavens with the $10\frac{1}{4}$-inch refractor on the early morning of July 23, I discovered a new, bright, telescopic comet in *Aries*. Its position was as follows : July 23, 13^h, Eastern standard time ; R.A., $2^h\ 43^m\ 40^s$; declination north, 12° 30′. The motion was rapid, about 3° daily, and almost due north. The comet had a bright stellar nucleus and a tail. It was really a very beautiful telescopic object, resembling a great naked eye comet in miniature.

In drawing fig. 1 I show its normal appearance shortly after discovery, which was maintained with very slight variation until the full moon interfered with the almost continuous obser-

vations at this observatory. There was noted, however, one remarkable exception. On July 26, at $13^h\ 25^m$, two branching wisps or streamers were seen issuing from either side of the coma,

FIG. 1. FIG. 2.

and making an angle of about thirty degrees with the principal tail. The northern streamer was the more prominent of the two.

Two hours later, or at $15^h\ 30^m$, on the same morning I could not detect the branching tails. The approximate position of the comet at this time was R.A. $2^h\ 46^m\ 35^s + 21°\ 16'$. On the following morning these streamers could not be seen, neither have I been able to detect them upon any subsequent occasion. The nucleus of the comet, which was remarkably sharp and well-defined, has always appeared elongated or pear-shaped. It has much resembled an unequal double star with the discs in contact. On two occasions it seemed possible to separate the nucleus with a sufficiently high power, but I was unable to do this with a magnifying power of 500 diameters.

On August 1 the comet was seen in the same low-power field with *Algol*.

My latest observation of the comet was last evening, August 8, when it was seen without difficulty in the presence of a nearly full Moon, and in R.A. $2^h\ 55^m\ 35^s + 59°\ 7'$. The comet is, therefore, now circumpolar, in *Camelopardalis*, and promises to be visible in moderate apertures for some time to come.

Smith Observatory, Geneva, N.Y., U.S.A.:
1900 *August* 9.

P.S.—Since the foregoing was written, it is learned from the *Ast. Nach.*, No. 3653, that the comet was independently dis-

covered by Borrelly the same morning. It is an interesting fact that although the difference in longitude of the two stations is about five hours, the Harvard cablegram announcing my discovery reached Kiel two hours before Borrelly's.

Nebulæ Discovered at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

During the twelve months ending 1900 June 30, the following nebulæ, supposed to be new, have been noted. The positions of all except one have been micrometrically measured, and are given for 1900·0. All owe their discovery to their proximity to known nebulæ, the places of which were being measured. In the "Descriptions" and "Notes" numbers enclosed in brackets refer to the Index Catalogue; others are the current ones of the N.G.C.

No.	Date.	R.A. h m s	Dec. ° ′	Descriptions
	1899.			
1	Nov. 6	0 30 28	− 3 25·7	eF, vS, in field with 161.
	1900.			
2	Jan. 1	1 18 57	− 2 10·6	eF, vS, possibly only a faint star.
3	Jan. 19	1 19 46	− 2 8·3	eF, eS; 530 is n.p.
4	Jan. 1	1 47 8	−17 16·9	eF, eS.
5	Jan. 1	1 48 11	−17 9·7	eF, eS.
	1899.			
6	Nov. 24	1 52 4	−17 1·7	F, eS.
	1900.			
7	Jan. 30	2 38 58	−16 7·7	vS, vF, mbM; near 1081.
8	Jan. 23	2 43 20	−14 24·6	eF, vS; near 1103.
9	Jan. 31	2 50 11	−16 3·5	vF, eS; almost stellar.
10	Jan. 30	3 1 38	−10 6·9	eF, S.
11	Jan. 22	3 4 1	−23 26·3	vF, L; near 1230.
12	Jan. 24	3 5 57	−11 10·6	eF, vS; near 1238.
13	Jan. 19	3 34 27	−15 49·6	eF, eS, v diffic.; near 1405.
14	Jan. 20	4 9 57	−13 25·5	eF, eS, almost stellar; near 1538.
15	Jan. 20	4 10 17	−13 26·5	eF, eS, diffic.; near 1538.
16	Jan. 31	4 27 25 ±	− 5 58 ±	eF, vS; f 1594, 90° ±, 3′n.
17	Jan. 22	5 48 12	−17 48·5	eF, pS; near (438).
18	Apr. 19	10 58 56	−19 33·3	vF, vS.
19	June 29	13 1 16	+54 13·2	vF, vS.
20	June 21	13 43 24	−29 47·8	F, cS, bM.
	1899.			
21	Sept. 11	18 12 41	+61 7·6	eF, eS, v diffic.; near 6617.
22	Nov. 25	23 19 47	+13 26·8	eF, eS; near 7651.
23	Nov. 27	23 33 27	+26 25·9	eF, eS; near 7720.
24	Nov. 27	23 33 38	+26 27·4	eF, eS; near 7720.

Notes.

No. 1 is attended by a star of mag. 14, a trifle south, and by another, which follows the nebula closely.

No. 2 is accompanied by a star of mag. 13, a trifle south preceding. The nebula is about 3′ from 530, which is identical with (106), the position of 530 in the N.G.C. being slightly erroneous. According to my measures, the position of 530 is $1^h\ 19^m\ 36^s - 2°\ 6'.5$; this agrees with Bigourdan's place for (106). No. 4 should perhaps be reckoned as identical with 690, though the N.G.C. place of the latter is $1^h\ 44^m\ 31^s - 17°\ 14'.0$ when reduced to 1900·0. However, Leavenworth's declinations are not apt to be so erroneous as would be the case if No. 4 were identical with 690. No. 6 is a star of mag. 11, with very slight outlying nebulosity.

No. 7 is equivalent in brightness to a star of mag. 13.

No. 10 is accompanied by a star of mag. 9 which follows eight seconds at the same declination.

No. 19 is near (847); 4973 and 4974, according to the N.G.C., follow No. 19 less than a minute of time; but their relative positions are not the same as those of (847) and No. 19. I looked for them on one night, when the seeing was poor, and could not be sure of them.

No. 22 precedes a star of mag. 9·5 thirteen seconds, 0′·2 north.

No. 24 looks like a star of mag. 13, blurred atmospherically. Other faint nebulæ are suspected in its vicinity.

No. 15 of the list in *M.N.* lviii. 9, has now been measured micrometrically, and its position is $12^h\ 45^m\ 43^s - 13°\ 57'.1$.

A nebula is suspected 5′ south of 4862. Two or three very faint nebulæ are suspected near 5664.

Ephemeris of Eros. By Frank Robbins.

In the *Astronomical Journal* (Vol. xix. No. 19, 451, 1898, December 12, page 155), Dr. S. C. Chandler, of Cambridge, U.S.A., has given the orbital elements upon which is founded the ephemeris now offered to the Royal Astronomical Society.

Dr. Chandler's elements were derived from the discussion of 142 observations, both visual and photographic, made at Berlin, Mount Hamilton, Washington, Harvard, and elsewhere, by the discoverer, De Witt, and by various observers, including Hussey, Frisby, Wendell, Barnard, and others, between 1898 August 17, and 1898 November 26, a comparatively short period with but few observations. Nevertheless the places derived from photographic observations made at Arequipa as long ago as 1893 December 19 (*Astronomical Journal*, Vol. xix. No. 19, 452, page 161), are not so very far from the computed places.

Knowing this when commencing this calculation in 1899 May, I did not try to improve the elements in any respect. In the time at my disposal it would have been impossible to extend the range of observations, confessedly somewhat limited, with a view

to the deduction of more accurate elements. To compute the perturbations produced by five planets during a period of 1116 (31 × 36) days and to obtain new elements for every thirty-sixth day is a heavy task when undertaken single-handed, nor is the work by any means concluded by the production of new orbital elements for the date of opposition. The prediction of heliocentric places at three-day intervals, and geocentric places for each noon and each transit involves much labour. For the perturbations produced by *Venus*, the Earth, *Mars*, *Jupiter*, and *Saturn*, I have employed the method of variation of constants as set forth in a paper (a perfect model for clearness and fulness of detail) by the late Astronomer Royal as an appendix to the *Nautical Almanac* for 1837, and illustrated by Woolhouse in the case of Halley's comet in the appendix for 1839.

This method does not lend itself to tabulation, and in consequence is somewhat laborious; however, it is not without its advantages. Using the method and the arrangement of formulæ employed at the *Nautical Almanac* office it was natural to adopt the data used there at the present time, in particular the following values of perturbing masses :—

log mass	*Venus*	4·39595
"	Earth	4·48395
"	*Mars*	3·50955
"	*Jupiter*	6·97969
"	*Saturn*	6·45573

In the actual calculations every effort has been made to secure accuracy, to which end the perturbations were calculated independently in duplicate by the writer and by Mr. J. Abner Sprigge of the *Nautical Almanac* office, while the heliocentric and geocentric places were carefully examined and differenced by the latter to the fourth, fifth, and sometimes even to the sixth order.

The opposition in right ascension occurs on October 30·41, and in longitude on November 11·04. The planet retrogrades in longitude from October 16 to December 15, and in right ascension from October 3 to December 5, and during the period covered by the ephemeris circles round γ *Andromedæ* at a distance of a few degrees. The greatest heliocentric latitude, 10° 50′·15 N., occurs on October 19, and the greatest geocentric latitude, 39° 38′·0 N., occurs on November 18. The planet is in perigee on December 26 at a distance 0·315.

The next opposition is in 1903 February. If this ephemeris appears to supply a need I may possibly calculate a similar ephemeris for that date, but in view of the number of astronomers who appear to be at work on this subject, I fear there is some danger of duplication.

I append the elements, &c., for mean equinox of 1900 November 1·5 :—

ϵ	66° 9′ 4″·2
π	121 11 21·4
ν	303 33 18·5
ι	10 50 16·5
ϕ	12 52 38·3
log a	0·1637863
n	2015″·2423
e	0·2228644.

Eros at Transit at Greenwich.

1900.	Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Dec. in 1 hour of long. ″	Mag.	Hor. Par. ″
Sept. 19	2 39 3·37	+1·68	N. 40 28 23·5	+57·1	10·9	13·3
20	2 39 42·32	+1·57	N. 40 51 14·3	+57·1	10·9	13·4
21	2 40 18·84	+1·47	N. 41 14 5·3	+57·1	10·9	13·6
22	2 40 52·85	+1·36	N. 41 36 56·1	+57·1	10·8	13·8
23	2 41 24·31	+1·26	N. 41 59 46·5	+57·1	10·8	13·9
24	2 41 53·09	+1·14	N. 42 22 35·7	+57·0	10·8	14·1
25	2 42 19·12	+1·02	N. 42 45 23·0	+57·0	10·7	14·3
26	2 42 42·29	+0·90	N. 43 8 8·0	+56·9	10·7	14·4
27	2 43 2·53	+0·78	N. 43 30 50·0	+56·7	10·7	14·6
28	2 43 19·75	+0·65	N. 43 53 28·0	+56·5	10·6	14·8
29	2 43 33·88	+0·52	N. 44 16 1·4	+56·3	10·6	14·9
30	2 43 44·82	+0·39	N. 44 38 29·7	+56·1	10·6	15·1
Oct. 1	2 43 52·51	+0·25	N. 45 0 52·2	+55·8	10·5	15·3
2	2 43 56·86	+0·11	N. 45 23 8·1	+55·5	10·5	15·5
3	2 43 57·79	−0·03	N. 45 45 16·6	+55·2	10·5	15·7
4	2 43 55·20	−0·18	N. 46 7 16·3	+54·8	10·4	15·9
5	2 43 49·02	−0·33	N. 46 29 6·2	+54·4	10·4	16·1
6	2 43 39·17	−0·49	N. 46 50 45·8	+53·9	10·4	16·3
7	2 43 25·52	−0·65	N. 47 12 14·0	+53·4	10·3	16·5
8	2 43 7·98	−0·81	N. 47 33 29·6	+52·9	10·3	16·7
9	2 42 46·42	−0·98	N. 47 54 31·5	+52·3	10·3	16·9
10	2 42 20·75	−1·16	N. 48 15 18·4	+51·6	10·2	17·1
11	2 41 50·92	−1·33	N. 48 35 49·2	+50·9	10·2	17·3
12	2 41 16·85	−1·51	N. 48 56 0·8	+50·1	10·2	17·5
13	2 40 38·47	−1·69	N. 49 15 51·9	+49·2	10·2	17·7

1900.		Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Decl. in 1 hour of long. ″	Mag.	Hor. Par. ″
Oct.	14	2 39 55.72	−1.87	N. 49 35 20.1	+48.2	10.2	17.9
	15	2 39 8.53	−2.06	N. 49 54 24.7	+47.2	10.1	18.1
	16	2 38 16.88	−2.25	N. 50 13 4.5	+46.1	10.1	18.3
	17	2 37 20.70	−2.44	N. 50 31 18.4	+45.0	10.1	18.6
	18	2 36 19.93	−2.63	N. 50 49 5.7	+43.9	10.1	18.8
	19	2 35 14.57	−2.82	N. 51 6 24.6	+42.7	10.0	18.9
	20	2 34 4.60	−3.01	N. 51 23 14.1	+41.4	10.0	19.1
	21	2 32 50.12	−3.19	N. 51 39 31.3	+40.0	10.0	19.3
	22	2 31 31.21	−3.38	N. 51 55 13.5	+38.5	9.9	19.5
	23	2 30 8.01	−3.56	N. 52 10 17.9	+36.8	9.9	19.7
	24	2 28 40.59	−3.73	N. 52 24 41.6	+35.1	9.9	20.0
	25	2 27 9.11	−3.89	N. 52 38 22.6	+33.3	9.8	20.2
	26	2 25 33.73	−4.05	N. 52 51 18.2	+31.4	9.8	20.4
	27	2 23 54.61	−4.20	N. 53 3 27.7	+29.5	9.8	20.6
	28	2 22 11.94	−4.35	N. 53 14 50.4	+27.5	9.7	20.8
	29	2 20 25.94	−4.48	N. 53 25 25.6	+25.4	9.7	21.0
	30	2 18 36.85	−4.60	N. 53 35 10.7	+23.3	9.7	21.2
	31	2 16 44.92	−4.71	N. 53 44 4.4	+21.1	9.6	21.4
Nov.	1	2 14 50.45	−4.82	N. 53 52 5.2	+18.9	9.6	21.6
	2	2 12 53.71	−4.91	N. 53 59 11.6	+16.6	9.6	21.8
	3	2 10 55.03	−4.98	N. 54 5 22.7	+14.3	9.6	22.0
	4	2 8 54.74	−5.04	N. 54 10 36.7	+11.9	9.6	22.2
	5	2 6 53.15	−5.09	N. 54 14 53.1	+ 9.5	9.5	22.4
	6	2 5 50.58	−5.12	N. 54 18 11.0	+ 7.0	9.5	22.6
	7	2 2 47.41	−5.14	N. 54 20 28.8	+ 4.5	9.5	22.8
	8	2 0 44.01	−5.14	N. 54 21 46.6	+ 2.0	9.5	23.0
	9	1 58 40.74	−5.12	N. 54 22 3.8	− 0.6	9.4	23.2
	10	1 56 38.00	−5.09	N. 54 21 19.6	− 3.1	9.4	23.4
	11	1 54 36.23	−5.04	N. 54 19 33.8	− 5.7	9.4	23.6
	12	1 52 35.85	−4.98	N. 54 16 46.0	− 8.3	9.3	23.8
	13	1 50 37.29	−4.89	N. 54 12 56.5	−10.9	9.3	24.0
	14	1 48 40.96	−4.79	N. 54 8 5.3	−13.4	9.3	24.2
	15	1 46 47.26	−4.67	N. 54 2 13.0	−16.0	9.3	24.3
	16	1 44 56.60	−4.54	N. 53 55 19.9	−18.5	9.3	24.5
	17	1 43 9.37	−4.39	N. 53 47 27.3	−20.9	9.2	24.7
	18	1 41 25.94	−4.22	N. 53 38 36.0	−23.3	9.2	24.8
	19	1 39 46.68	−4.04	N. 53 28 47.0	−25.7	9.2	25.0
	20	1 38 11.94	−3.85	N. 53 18 1.5	−28.0	9.2	25.2

1900.	Apparent Right Ascension. h m s	Var. of R.A. in 1 hour of long. s	Apparent Declination. ° ′ ″	Var. of Dec. in 1 hour of long. ″	Mag.	Hor. Par. ″
Nov. 21	1 36 42·06	−3·64	N. 53 6 21·1	−30·3	9·2	25·3
22	1 35 17·37	−3·42	N. 52 53 47·2	−32·5	9·2	25·4
23	1 33 58·13	−3·19	N. 52 40 21·5	−34·6	9·1	25·6
24	1 32 44·61	−2·94	N. 52 26 6·3	−36·6	9·1	25·7
25	1 31 37·01	−2·69	N. 52 11 3·2	−38·5	9·1	25·8
26	1 30 35·55	−2·43	N. 51 55 14·3	−40·4	9·1	26·0
27	1 29 40·40	−2·16	N. 51 38 41·9	−42·2	9·1	26·1
28	1 28 51·69	−1·89	N. 51 21 28·2	−43·9	9·1	26·2
29	1 28 9·55	−1·62	N. 51 3 35·0	−45·5	9·0	26·4
30	1 27 34·04	−1·34	N. 50 45 4·6	−47·0	9·0	26·5
Dec. 1	1 27 5·21	−1·06	N. 50 25 58·5	−48·4	9·0	26·6
2	1 26 43·09	−0·78	N. 50 6 18·8	−49·8	9·0	26·7
3	1 26 27·71	−0·50	N. 49 46 7·3	−51·1	9·0	26·8
4	1 26 19·02	−0·22	N. 49 25 25·8	−52·3	9·0	26·9
5	1 26 17·03	+0·06	N. 49 4 16·1	−53·4	8·9	27·0
6	1 26 21·67	+0·33	N. 48 42 40·1	−54·5	8·9	27·1
7	1 26 32·92	+0·61	N. 48 20 39·1	−55·5	8·9	27·2
8	1 26 50·73	+0·88	N. 47 58 14·9	−56·5	8·9	27·3
9	1 27 15·03	+1·15	N. 47 35 29·1	−57·3	8·9	27·3
10	1 27 45·79	+1·41	N. 47 12 23·0	−58·1	8·9	27·4
11	1 28 22·94	+1·68	N. 46 48 58·1	−58·9	8·9	27·4
12	1 29 6·42	+1·94	N. 46 25 16·1	−59·6	8·9	27·5
13	1 29 56·16	+2·20	N. 46 1 18·0	−60·2	8·9	27·5
14	1 30 52·07	+2·46	N. 45 37 5·2	−60·8	8·9	27·6
15	1 31 54·08	+2·71	N. 45 12 38·7	−61·4	8·9	27·6
16	1 33 2·11	+2·96	N. 44 47 59·5	−61·9	8·9	27·7
17	1 34 16·04	+3·20	N. 44 23 9·4	−62·3	8·8	27·7
18	1 35 35·77	+3·44	N. 43 58 9·9	−62·6	8·8	27·8
19	1 37 1·18	+3·68	N. 43 33 2·4	−63·0	8·8	27·8
20	1 38 32·18	+3·91	N. 43 7 47·5	−63·3	8·8	27·8
21	1 40 8·62	+4·13	N. 42 42 25·9	−63·6	8·8	27·8
22	1 41 50·41	+4·35	N. 42 16 57·9	−63·8	8·8	27·8
23	1 43 37·46	+4·57	N. 41 51 25·7	−63·9	8·8	27·9
24	1 45 29·68	+4·78	N. 41 25 49·7	−64·0	8·8	27·9
25	1 47 26·93	+4·99	N. 41 0 11·7	−64·1	8·8	27·9
26	1 49 29·11	+5·19	N. 40 34 31·4	−64·2	8·8	27·9

Note on the accuracy of the Star Charts published by the French Observatories as reproductions of their Plates for the Astrographic Chart. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. The French observatories which are taking a share in the International Astrographic Chart (Paris, Algiers, Bordeaux, Toulouse)* have already published a number of large paper sheets, reproducing by heliogravure the long-exposure plates on a scale of 2^{mm} to 1′ (twice that of the original negatives). These reproductions are very beautiful, but apparently somewhat expensive. From figures mentioned at the meeting of the Permanent Committee last July, it would seem that it would cost each observatory about 10,000*l.* to reproduce their plates in this way. Now some of the participating observatories will not find it easy to obtain a sum of this kind for the work; and it becomes important to know what we may expect in return, and especially what is the order of accuracy of these maps. We have not been hitherto accustomed to associate any very great accuracy with paper star maps. They represent well enough the general configurations of the stars, but have not been intended for exact measurement. The charts of *Argelander* and *Chacornac*, for instance, do not always give the places correctly to 1′; a case has been quoted (see *Mem. R. A. S.*, vol. lii., p. 184) where one of the latter is in error for 3′ or 4′ over a sensible area. No such errors are likely to occur in photographic reproductions, but very little has been published to show what accuracy can be obtained from paper prints. Five years ago I showed that a very considerable accuracy was attainable in contact prints (*Monthly Notices*, vol. lvi., p. 26); and in this paper it was stated that the images on the prints, especially of the réseau-lines, were rather diffuse, so that better results might be expected when attention was paid to securing better images.

2. No opportunity for continuing the investigation has presented itself until recently, when a portion of one of the beautiful reproductions of the Paris Observatory was examined. These measures are not sufficiently extended to settle the question of accuracy completely, but may serve to draw attention to the need for settling it. They seem to indicate that *we can get star-places from these paper charts at least as good as those obtained with meridian instruments.* On finding this result, I wrote to M. Loewy and M. Trépied, suggesting that a much more complete investigation could be made by comparing measures of these paper reproductions with measures of the original negatives; and a courteous reply was at once received, saying that the investigation should be undertaken. At the same time a wish was

* We have also recently received two sheets of the same kind from the San Fernando Observatory.

expressed that these measures should be published. They have the incompleteness and roughness of a preliminary investigation, but the necessity of attending to the Opposition of *Eros* prevents the thorough revision that might otherwise be given to them; and they will at least serve the purpose, as remarked above, of drawing attention to an important matter.

3. The whole of the work was done by Mr. F. C. H. Carpenter, Assistant at the Durham Observatory. Mr. Carpenter was for some years at the University Observatory, Oxford, which he left for his appointment at Durham, and during a recent holiday visit to Oxford he requested permission to measure and reduce a few plates as in the old days (a request which was naturally gratifying, as showing that such work is not irksome), and I suggested that, instead of measuring one of the regular plates of our zone, he should make some measures on one of the Paris charts in zone $+24°$, which overlaps our zone $+25°$, and compare them with measures on an Oxford plate, in order to test the accuracy of the paper charts. He willingly assented, and what follows is the result of his work.

4. The Paris chart selected had centre at $+24°$, $20^h\ 40^m$, and the Oxford plate $+25°$, $20^h\ 44^m$. The quarter-plate of the paper chart overlapping the Oxford plate was carefully cut out along the bounding réseau-lines, and placed between two pieces of plate-glass. Being on twice the linear scale, the quarter plate was about the size of one of the ordinary plates, and could be fitted into one of the regular measuring machines; but, of course, the squares of the réseau on it were just twice as broad as those on an ordinary plate. Hence the cross-scales in the eye-piece of the measuring machine (for description see *Monthly Notices*, vol. lv., p. 102), instead of each cutting *two* réseau-lines, could only each cut *one*. In the ordinary way we get with this machine two readings for each coordinate, say x_1 x_2 and y_1 y_2; such that the differences x_1-x_2 and y_1-y_2 are small, and indicate the correction for "runs" (*i.e.* want of equality between 100 div. of the scales and one réseau interval). With the paper chart we get either x_1 or x_2, but not both; and thus have no correction for runs, which is important in measuring a paper reproduction. Fortunately the squares were generally just a little smaller than the total length of the scale; so that the corrections for runs, although not obtainable incidentally in measuring the star, could be got from a separate operation by setting the four ends of the two scales just on réseau-lines. The corrections thus obtained were assumed to apply to the whole square, and the *single* measures of each coordinate were then corrected for runs. But it will be obvious that here we have sources of inaccuracy due to the method of measurement, and not to the charts themselves. Better methods of measurement could readily be devised; but in this preliminary investigation this method, ready to hand, was considered sufficient.

5. As the paper chart, with exposures of 30^m, contained more

stars than the Oxford plate with exposures 6^m and 3^m, it was advisable to identify the stars to be measured on the former. From a few selected stars provisional linear formulæ were found connecting coordinates on one plate with those on the other; and the Oxford measures were then reduced, by use of these formulæ, to approximate accordance with the paper chart.

6. Measures were then made on the chart by setting the cross of the scale by estimation *in the centre of the triangle formed by the three images.* Here again is a probable inaccuracy, due merely to the method of measurement. By selecting one of the images, or better still, by measuring all three, the accuracy of the present measures could almost certainly be improved.

7. *Ninety* stars were then measured and compared. From *twenty* of these, four equations were formed in the ordinary way to find the exact linear formulæ connecting the two plates. The small corrections of the second order, due to the difference of centres of the plates, were at first neglected as probably representing too high an order of accuracy for this investigation; but were afterwards applied when it was found how accurate the measures were.

8. Applying the linear corrections found to the differences, the ninety residuals were found to be grouped as follows:—

Residual.	No. of cases. In x.	No. of cases. In y.	Residual.	No. of cases. In x.	No. of cases. In y.
$+8 = +2''.4$	1	0	$0 \quad 0''.0$	10	17
$+7 = +2.1$	0	1	$-1 = -0.3$	19	10
$+6 = +1.8$	0	2	$-2 = -0.6$	12	9
$+5 = +1.5$	3	5	$-3 = -0.9$	11	5
$+4 = +1.2$	5	4	$-4 = -1.2$	4	4
$+3 = +0.9$	5	10	$-5 = -1.5$	4	3
$+2 = +0.6$	4	12	$-6 = -1.8$	0	1
$+1 = +0.3$	12	8	$-7 = -2.1$	0	1

Allowing for the two sources of inaccuracy above indicated, these differences show that the measures made on the paper chart are very nearly, if not quite, as good as the measures made on our Catalogue plates. The probable error of a single measure on the paper chart is not much greater than $0''.3$, though in view of the provisional nature of the measures, it does not seem worth while to give an exact value to it.

It should further be remarked that the stars measured were of all sizes. The larger stars do not show the three images separated, but only a triangular patch; the charts are not meant to give the places of these with great accuracy.

9. In conclusion I would venture to add one remark with regard to the construction of these charts. If these indications of their accuracy are confirmed and extended by measures made under more favourable conditions at the French observatories,

may it not be well to reconsider the practice of adding any finishing touches by hand? I gathered at the meeting of the Committee last July that a few touches are occasionally necessary—to insert stars accidentally omitted, &c. It seems improbable that these can be made with the accuracy which characterises the rest of the chart, and it might be well at least to indicate clearly in the margin where any artificial additions have been made. But I may have misunderstood what is done.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Years 1898 *and* 1899. By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *Naut. Alm.*
1898.					h m s	h m s
Mar. 29	I.	Tr. Egr.	Int. contact	168	23 7 43	
29	I.	,,	Bisection	,,	23 9 13	23 14
29	I.	,,	Ext. contact	,,	23 13 37	
30	II.	,,	Int. contact	,,	22 5 54	
30	II.	,,	Bisection	,,	22 8 9	22 12
30	II.	,,	Ext. contact	,,	22 12 18	
30	III.	Tr. Ingr.	Ext. contact	,,	23 11 18	
30	III.	,,	Bisection	,,	23 18 2	23 17
30	III.	,,	Int. contact	,,	23 23 11	
Apr. 6	Shd. I.	Transit	On cent. merid.	74	0 7 0	
6	II.	Tr. Ingr.	Ext. contact	168	21 54 27	
6	II.	,,	Bisection	,,	21 57 11	21 56
6	II.	,,	Int. contact	,,	21 59 46	
6	I.	Ecl. R.	First seen	74	22 23 59	22 24 13
13	I.	Occ. D.	First contact	168	21 37 37	
13	I.	,,	Bisection	,,	21 39 17	21 38
13	I.	,,	Last seen	,,	21 40 56	
14	II.	Tr. Ingr.	Ext. contact	,,	0 8 57	
14	II.	,,	Bisection	,,	0 11 21	0 9
14	II.	,,	Int. contact	,,	0 14 41	
14	I.	Ecl. R.	First seen	74	0 17 56	0 18 10
14	I.	,,	Full brightness	,,	0 21 30	
18	III.	,,	First seen	,,	0 18 42	0 19 19
18	III.	,,	Full brightness	,,	0 29 0	
May 30	I.	Tr. Egr.	Ext. contact	168	20 55 3	20 54
30	III.	Ecl. D.	Began to fade	74	21 37 6	
30	III.	,,	Last seen	,,	21 47 28	21 42 0

Day of Obs. 1899.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *Naut. Alm.* h m s
Apr. 21	III.	Tr. Ingr.	Ext. contact	168	22 53 42	
21	III.	„	Bisection	„	23 2 35	23 1
21	III.	„	Int. contact	„	23 11 29	
21	III.	Tr. Egr.	Int. contact	„	23 48 32	
21	III.	„	Bisection	„	23 57 41	24 10
22	III.	„	Ext. contact	„	0 7 54	
23	II.	Ecl. D.	Began to fade	132	23 29 7	
23	II.	„	Last seen	„	23 32 17	23 32 10
May 2	I.	Occ. D.	First contact	230	23 3 4	
2	I.	„	Bisection	„	23 4 48	23 4
2	I.	„	Last seen	„	23 7 8	
3	I.	Tr. Egr.	Int. contact	„	22 21 54	
3	I.	„	Bisection	„	22 23 59	22 26
3	I.	„	Ext. contact	„	22 26 58	
18	I.	Occ. D.	First contact	168	20 56 35	
18	I.	„	Bisection	„	20 59 25	20 59
18	I.	„	Last seen	„	21 1 24	
18	II.	Ecl. R.	First seen	74	22 53 35	22 55 44
18	II.	„	Full brightness	„	22 57 20	
18	I.	„	First seen	„	23 40 41	23 41 5
18	I.	„	Full brightness	„	23 43 47	
19	I.	Tr. Egr.	Int. contact	168	20 17 25	
19	I.	„	Bisection	„	20 20 20	20 23
19	I.	„	Ext. contact	„	20 23 39	
25	II.	Occ. D.	First contact	„	21 48 30	
25	II.	„	Bisection	„	21 51 14	21 52
25	II.	„	Last seen	„	21 56 49	
25	I.	„	First contact	„	22 43 26	
25	I.	„	Bisection	„	22 45 30	22 44
25	I.	„	Last seen	„	22 47 5	
June 9	I.	Tr. Ingr.	Ext. contact	„	23 29 28	
9	I.	„	Bisection	„	23 31 23	23 33
9	I.	„	Int. contact	„	23 33 47	
10	I.	Occ. D.	First contact	74	20 40 30	
10	I.	„	Bisection	„	20 44 10	20 45
10	I.	„	Last seen	„	20 46 34	
10	II.	Tr. Ingr.	Ext. contact	„	21 0 37	
10	II.	„	Bisection	„	21 5 26	21 4

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *Naut. Alm.*
1899.					h m s	h m s
June 10	II.	Tr. Ingr.	Int. contact	74	21 9 31	
10	III.	"	Bisection	"	22 20 34	22 21
10	III.	"	Int. contact	"	22 26 53	
10	II.	Tr. Egr.	Int. contact	"	23 21 49	
10	II.	"	Bisection	"	23 25 18	23 23
10	II.	"	Ext. contact	"	23 30 47	
10	I.	Ecl. R.	First seen	"	23 52 10	23 52 26
10	I.	"	Full brightness	"	23 54 43	
10	III.	Tr. Egr.	Int. contact	"	23 55 53	
11	III.	"	Bisection	"	0 3 12	0 6
11	III.	"	Ext. contact	"	0 11 50	
July 26	I.	Occ. D.	First contact	70	20 49 22	
26	I.	"	Bisection	"	20 51 31	20 51
26	I.	"	Last seen	"	20 53 6	
27	I.	Ecl. R.	First seen	"	0 17 28	0 17 27
27	I.	"	Full brightness	"	0 19 22	
28	II.	Occ. R.	Last contact		22 38 22	22 38
28	II.	Ecl. D.	Began to fade		22 49 20	
28	II.	"	Last seen		22 54 24	22 53 16
Sept. 19	I.	Ecl. R.	First seen	70	21 6 46	21 6 59
19	I.	"	Full brightness	"	21 10 4	

Notes.

1898.
March 29.—Definition only occasionally good.
March 30.—Definition fairly good for Satellite II., and good for Satellite III.
April 6.—Transit of shadow estimated. Definition of II. pretty satisfactory; but the eclipse of I. was observed through cloud with full moon present.
April 13 and 14.—Sky beautifully clear; steadiness and definition pretty satisfactory throughout.
April 18.—Sky beautifully clear; images steady and well defined.
May 30.—Definition excellent and observation of contact unusually good. Sky clear and definition good at the eclipse. Satellite suspected five or six seconds later.

1899.
April 21 and 22.—Satellite visible throughout the transit as a bright disc. Definition was generally pretty good and occasionally very good. It was extremely difficult to fix the times of the phases in consequence of the oblique path of the satellite across the planet's limb.
April 23.—Definition pretty good, but Moon near her opposition and not far from planet.
May 2.—Definition pretty good, but last phase difficult to observe.
May 3.—Images tremulous and definition bad.

1899.
May 18.—Definition pretty good throughout. The first phase of the eclipse of II. was observed rather late. The eclipse of I. was well observed. Sky beautifully clear, but Moon present.
May 19.—Definition bad and images tremulous.
May 25.—Definition pretty good.
June 9.—Definition bad and images tremulous.
June 10 and 11.—Definition bad and images tremulous; a higher power could not be employed.
July 26.—Definition good and images steady.
July 27.—Observation rather late, the satellite being rather conspicuous. The recorded minute was doubtful.
July 28.—Steadiness and definition satisfactory, but impossible to observe the final disappearance within five seconds. Clouds prevented an observation of the reappearance. This is, I believe, the third time a disappearance of the second satellite has been observed at Windsor after the planet's opposition, and the systematic observations taken here extend over a period of thirty-five years.
September 19.—Sky clear and definition pretty good, but Moon just risen.

An occulting bar was not employed in the observations. The times given are the Windsor mean times of observation diminished by 10 hrs. 3 mins. 20·5 secs., and entered to the nearest second. The observations of full brightness in the eclipses are at the best only rough approximations. In determining these times the increasing light of the satellite was repeatedly compared with the other visible satellites. The observations of July 28 were made with the 4½-inch telescope, and all the others with the 8-inch instrument.

Observatory, Peninsula, Windsor, N. S. Wales:
1900 *August* 25.

Erratum in MONTHLY NOTICES, vol. lx.

P. 570, line 9 from top, *for* Approx. *read* Apparent.

LIST OF WORKS

PRESENTED TO THE SOCIETY,

AND OF

WORKS PURCHASED WITH THE TURNOR AND HORROX FUND,

JUNE 1899 TO JUNE 1900.

An asterisk (*) indicates that the work is an excerpt.

Acta Mathematica. Zeitschrift, herausgegeben von G. Mittag-Leffler, Band 22, pt. 4—Band 23, pt. 2.
(*Turnor and Horrox Fund.*) 4to. Stockholm, 1899

Adelaide, Government Observatory:
Meteorological Observations made at the Adelaide Observatory and other places in South Australia and the Northern Territory during the year 1896, under the direction of C. Todd.
(*Observatory.*) fol. Adelaide, 1899

Aitken (R. G.):
*Measures of double stars in 1898.
(*Author.*) 4to. Kiel, 1899

Allen (R. H.):
Star names and their meanings.
(*Turnor and Horrox Fund.*) 8vo. New York, 1899

Ambronn (L.):
Handbuch der astronomischen Instrumentenkunde. Eine Beschreibung der bei astronomischen Beobachtungen benutzten Instrumente, sowie Erläuterung der ihrem Bau, ihrer Anwendung und Aufstellung zu Grunde liegenden Principien.
(*Author.*) 2 vols. 4to. Berlin, 1899

American Academy of Arts and Sciences:
Proceedings, Vol. 34, No. 18—Vol. 35, No. 16.
(*Academy.*) 8vo. Boston, Mass., 1899–1900

American Journal of Mathematics. Edited by T. Craig and S. Newcomb. Published under the auspices of the Johns Hopkins University. Vol. 21, No. 4—Vol. 22, No. 2.
(*Editors.*) 4to. Baltimore, 1899–1900

American Journal of Science. Editor E. S. Dana [and others]. Fourth series, Vol. 8, 9 (No. 43–54).
(*Editors.*) 8vo. New Haven, 1899–1900

American Philosophical Society:
—— : Proceedings, Vol. 37, No. 159–160.
(*Society.*) 8vo, Philadelphia, 1899
—— : Transactions. New series, Vol. 20, pt. 1.
(*Society.*) 4to. Philadelphia, 1899

Amsterdam, Koninklijke Akademie van Wetenschappen:
—— : Verhandelingen (Eerste Sectie), Deel 6, pt. 6; Deel 7, pt. 1.
(*Academy.*) 8vo. Amsterdam, 1899
—— : Verslagen van de gewone Vergaderingen der Wis- en Natuurkundige Afdeeling, 1898–99. Deel 7.
(*Academy.*) 8vo. Amsterdam, 1899
—— : Proceedings of the section of Sciences, vol. 1.
(*Academy.*) 8vo. Amsterdam, 1899
—— : Jaarboek, 1898.
(*Academy.*) 8vo. Amsterdam, 1899

Angelitti (Filippo):
*Formole e teoremi relativi all' ellissoide terrestre, e calculo nell' ellissoide di Bessel di alcuni elementi per la latitudine di Capodimonte. Memoria prima.
(*Author.*) 4to. Napoli, 1898

Antoniadi (Eugene Michael):
*Le maximum des taches solaires en 1893.
(*Author.*) 8vo. Paris, 1894

Arcetri, Reale Osservatorio:
Pubblicazioni del R. Istituto di studi superiori pratici e di perfezionamento, fasc. 10.
(*Observatory.*) 4to. Firenze, 1899
A. Abetti. Osservazioni astronomiche fatte . . . 1898

Arcidiacono (S.):
—— : *Sui terremoti del 3 maggio, 1899.
(*Author.*) 8vo. Catania, 1899
—— : *Principali fenomeni eruttivi avvenuti in Sicilia e nelle isole adiacenti, 1898.
(*Author.*) 8vo. Modena, 1899

Astronomical and Astrophysical Society of America:
First meeting, 1899.
(*Society.*) 8vo.

Astronomical Journal. Founded by B. A. Gould [edited by S. C. Chandler]. Vol. 20, 21 (No. 464–483).
(*Editor.*) 4to. Boston, 1899–1900

Astronomische Mittheilungen. Gegründet von Rudolph Wolf, herausgegeben von A. Wolfer. No. 90.
(*Editor.*) 8vo. Zürich, 1899

Astronomische Nachrichten. Begründet von H. C. Schumacher, herausgegeben von H. Kreutz. Band 149–152 (No. 3573–3642).
(*Editor.*) 4to. Kiel, 1899–1900

Astronomische Rundschau. Herausgegeben von der Manora-Sternwarte in Lussinpiccolo (Oesterreich), unter der verantwortlichen Redaction von Leo Brenner. Band 1, Heft 5—Band 2, Heft 15.
(*Turnor and Horrox Fund.*) 8vo. Altenburg, 1899–1900

Astrophysical Journal (the). An International Review of spectroscopy and astronomical physics. Edited by G. E. Hale and J. E. Keeler [&c.] Vol. 9, No. 5—Vol. 11, No. 5.
(*Editors.*) 8vo. Chicago, 1899–1900

Athenæum (the). Journal of English and foreign literature, science, the fine arts, music, and the drama, 1899–1900. (No. 3737–3788.)
(*Editor.*) 4to. London, 1899–1900

Athens, Observatoire National:
Annales . . . publiées par Demétrius Eginitis. Tome 1–2.
(*Observatory.*) 4to. Athènes, 1898–1900

Australasian Association for the Advancement of Science:
Report of the seventh meeting . . . held at Sydney, 1898.
(*Association.*) 8vo. Sydney, 1898

Ball (R. S.):
Star-land: being talks with young people about the wonders of the heavens. New and revised edition.
(*M. C. Sharp.*) 8vo. London, 1899

Baltimore, Johns Hopkins University:
Circular, No. 139–143.
(*University.*) 4to. Baltimore, 1899–1900

Barbera (Luigi):
Critica del Newtonianismo, ovvero delle cause dei moti planetarii.
(*Author.*) 4to. Bologna, 1900 [1899]

Barnard (Edward Emerson):
—— : *The development of photography in astronomy. Address . . . American Association for the Advancement of Science.
(*Author.*) 8vo. Salem, Mass., 1898
—— : * Micrometrical measures of the fifth satellite of *Jupiter*, and on the motion of the line of apsides of the orbit of the satellite.
(*Author.*) 4to. Boston, 1899

Batavia, Koninklijke Natuurkundige Vereeniging in Nederlandsch-Indië:
Natuurkundig Tijdschrift voor Nederlandsch-Indië. Deel 58 (Serie 10, Deel 2).
(*Society.*) 8vo. Batavia, 1899

Batavia, Royal Magnetical and Meteorological Observatory:
——: Observations . . . published by order of the Government of Netherlands India. Vol. 21, 1898.
(*Observatory.*) 4to. Batavia, 1899
——: W. van Bemmelen, Die Abweichung der Magnetnadel-Beobachtungen, Säcular-Variation, Wert- und Isogonensysteme bis zur Mitte des xviiiten Jahrhunderts. [Supplement to vol. 21 of "Observations"].
(*Observatory.*) 4to. Batavia, 1899
——: * Regenwaarnemingen in Nederlandsch-Indië, Jaargang 20, 1898.
(*Observatory.*) 8vo. Batavia, 1899

Belfast Natural History and Philosophical Society:
Report and proceedings . . . for the session 1898–1899.
(*Society.*) 8vo. Belfast, 1899

Bergstrand (Östen):
Undersökningar öfver stellarfotografiens användning vid bestämningen af fixstjärnornas årliga parallaxer.
(*Upsala Observatory.*) 8vo. Upsala, 1899

Berlin, Centralbureau der Internationalen Erdmessung:
——: Anleitung zum Gebrauche des Zenitteleskops auf den internationalen Breitenstationen, von Th. Albrecht.
(*Bureau.*) 4to. Berlin, 1900
——: Bericht über den Stand der Erforschung der Breitenvariation am Schlusse des Jahres 1899.
(*Bureau.*) 4to. Berlin, 1900

Berlin, Deutsche physikalische Gesellschaft:
Verhandlungen, Jahrgang 1, No. 8—Jahrgang 2, No. 9.
(*Society.*) 8vo. Berlin, 1899–1900

Berlin, Königlich Astronomisches Rechen-Institut:
——: Berliner Astronomisches Jahrbuch für 1902; mit Angaben für die Oppositionen der Planeten (1)–(440) für 1900. Herausgegeben . . . unter Leitung von J. Bauschinger.
(*Institute.*) 8vo. Berlin, 1900
——: Veröffentlichungen, No. 10–11.
(*Institute.*) 4to. Berlin, 1899–1900

10. J. Bauschinger [&c.], Genäherte Oppositions-Ephemeriden von 32 kleinen Planeten, 1899.
11. J. Bauschinger [&c.], Genäherte Oppositions-Ephemeriden von 67 kleinen Planeten, 1900.

Berlin, Königlich preussische Akademie der Wissenschaften:
—— : Abhandlungen, 1898.
(*Academy.*) 4to. Berlin, 1898
—— : Sitzungsberichte, 1899, No. 23—1900, No. 22.
(*Academy.*) 8vo. Berlin, 1899–1900

Berlin, Königliche Sternwarte:
Beobachtungs-Ergebnisse . . . Heft 8. Resultate aus Beobachtungen . . . angestellt in den Jahren 1892–97 . . . von H. Battermann.
(*Observatory.*) 4to. Berlin, 1899

Berlin, Physikalische Gesellschaft:
Die Fortschritte der Physik im Jahre 1898, dritte Abtheilung, enthaltend kosmische Physik, redigirt von Richard Assmann. Jahrgang 54.
(*Society.*) 8vo. Braunschweig, 1900

Berlin, Vereinigung von Freunden der Astronomie und Kosmischen Physik:
Mittheilungen, Jahrgang 9, No. 4—Jahrgang 10, No. 4.
(*Turnor and Horrox Fund*) 8vo. Berlin, 1899–1900

Berthon (Edward Lyon):
A retrospect of eight decades.
(*Author.*) 8vo. London, 1899

Bickerton (A. W.):
—— : A new story of the stars.
(*Author.*) 8vo. Christchurch, N.Z.
—— : *Some recent advances in favour of impact.
(*Author.*) 8vo. Wellington, N.Z., 1894

Boffito (Giuseppe):
* Un poeta della Meteorologia : Gioviani Pontano.
(*Author.*) 4to. Napoli, 1899

Bombay Branch of the Royal Asiatic Society:
Journal, Vol. 20, No. 54.
(*Society.*) 8vo. Bombay, 1898

Bombay, Government Observatory:
—— : Magnetical and Meteorological Observations made . . . 1897.
(*Observatory.*) fol. Bombay, 1898
—— : Report . . . 1898–99.
(*Observatory.*) fol. Bombay, 1899

Bonn, Königliche Sternwarte:
Veröffentlichungen . . . herausgegeben vom Direktor, Fr. Küstner. No. 4.
(*Observatory.*) 4to. Bonn, 1900
C. Mönnichmeyer, Beobachtungen von 4070 Sternen . . . ausgeführt und bearbeitet von F. Küstner.

Boston, American Academy of Arts and Sciences:
Proceedings. Vol. 34, No. 18—Vol. 35, No. 16.
(*Academy.*) 8vo. Boston, Mass., 1899–1900

Bouché-Leclerq (A.):
L'astrologie Grecque.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1899

Boulton (M. P. W.):
On solar or stellar heat.
(*Turnor and Horrox Fund.*) 8vo. London, 1891

Brédikhine (Théodore):
* Sur les radiants composés (dits stationnaires) des étoiles filantes.
(*Author.*) 4to. St.-Pétersbourg, 1900

Brenner (Leo):
*Thätigkeit der Manora-Sternwarte im Jahre 1899.
(*Author.*) 4to. Berlin, 1900

Brisbane, Queensland Branch of the Royal Geographical Society of Australasia:
Proceedings and transactions, session 14, 1898–99, Vol. 14.
(*Society.*) 8vo. Brisbane, 1900

British Association for the Advancement of Science:
Report of the 69th meeting, 1899.
(*Association.*) 8vo. London, 1900

[Brown (J. H.)]:
The maintenance of solar energy; or preliminary notes on the evolution and devolution of the solar system. By F.R.A.S.
(*Author*). 8vo. London, 1899

Brown (Robert), Jun.:
Researches into the origin of the primitive constellations of the Greeks, Phœnicians, and Babylonians. Vol. 1.
(*W. T. Lynn.*) 8vo. London, 1899

Browne (R. G. M.):
* The apparently altered size of celestial objects through change of altitude.
(*Author.*) 8vo. London, 1900

Brussels, Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique:
—— : Bulletins, 3me série, année 67–68. Tome 34–36.
(*Academy.*) 8vo. Bruxelles, 1897–98
—— : Mémoires, tome 53.
(*Academy.*) 4to. Bruxelles, 1895–98
—— : Mémoires couronnés et mémoires des savants étrangers. Tome 55, 56.
(*Academy.*) 4to. Bruxelles, 1896–98

Brussels, Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique—*continued.*
——: Mémoires couronnés et autres mémoires. (Collection in 8vo.) Tome 55, 57, 58.
(*Academy.*) 8vo. Bruxelles, 1898
——: Tables générales du Recueil des Bulletins . . . 3me série, tome 1–30 (1881–95).
(*Academy.*) 8vo. Bruxelles, 1898
——: Tables générales des Mémoires . . . 1772–1897.
(*Academy.*) 8vo. Bruxelles, 1898
——: Annuaire, année 64, 65.
(*Academy.*) 8vo. Bruxelles, 1898-99

Brussels, Observatoire Royal de Belgique:
——: Annuaire, 1900. Année 67.
(*Observatory.*) 16mo. Bruxelles, 1900
——: Bulletin mensuel du magnétisme terrestre . . . par L. Niesten. 1899 Jan.–Oct.; 1900 Jan., Fév.
(*Observatory.*) 8vo. Bruxelles, 1899–1900

Bryan (Margaret):
A compendious system of astronomy, in a course of familiar lectures . . . also a key to the ephemeris and a vocabulary of the terms of science.
(*Turnor and Horrox Fund.*) 8vo. London, 1805

Budapest, Königl. Ungarische Reichsanstalt für Meteorologie und Erdmagnetismus:
Jahrbücher, Jahrgang 1898; Band 28, Theil 2.
(*Institute.*) 4to. Budapest, 1899

Budapest, Magyar Tudományos Akadémia:
——: Almanach, 1899.
(*Academy.*) 8vo. Budapest, 1899
——: Mathematikai és természettudományi Értesitö. Kotet 16, 3–5; Kotet 17, 1, 2.
(*Academy.*) 8vo. Budapest, 1898–99
——: Mathematikai és természettudományi Közlemények. Kotet 27, 3.
(*Academy.*) 8vo. Budapest, 1899
——: Mathematische und naturwissenschaftliche Berichte aus Ungarn. Band 15.
(*Academy.*) 8vo. Budapest, 1899
——: Rapport sur les travaux de l'Académie Hongroise des Sciences en 1898.
(*Academy.*) 8vo. Budapest, 1899

Bulletin Astronomique. Fondé en 1894 par E. Mouchez et F. Tisserand. Publié par l'Observatoire de Paris. Tome 16, No. 7—Tome 17, No. 5.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1899–1900

Bulletin des Sciences Mathématiques. Rédigé par G. Darboux et J. Tannery. Série 2. 1899—1900, Tome 23, No. 4, Tome 24, No. 2.
(*Editors.*) 8vo. Paris, 1899–1900

Byrd (Mary E.):
A laboratory manual in astronomy.
(*Turnor and Horrox Fund.*) 8vo. Boston, Mass., 1899

Calcutta, Asiatic Society of Bengal:
—— : Journal, Part 2, Vol. 68, No. 1–3.
(*Society.*) 8vo. Calcutta, 1899–1900
—— : Journal, Part 3, Vol. 68, No. 1.
(*Society.*) 8vo. Calcutta, 1899
—— : Proceedings, 1899, No. 4—1900, No. 1.
(*Society.*) 8vo. Calcutta, 1899–1900

Cambridge Philosophical Society:
—— : Proceedings, Vol. 10, No. 2–5.
(*Society.*) 8vo. Cambridge, 1899–1900
—— : Transactions, Vol. 17, pt. 3; Vol. 18.
(*Society.*) 8vo. Cambridge, 1899–1900
Vol. 18. Memoirs presented . . . on the occasion of the Jubilee of Sir G. G. Stokes.

Campbell (W. W.):
The elements of practical astronomy. Second edition.
(*Turnor and Horrox Fund.*) 8vo. New York, 1899

Canada, Department of Marine [&c.]:
Report of the Meteorological Service of Canada, by R. F. Stupart, Director. 1896; Vol. 1, 2.
(*Department.*) 4to. Ottawa, 1898

Canada, Geological Survey:
Annual Report (new series). Vol. 10, 1897.
(*Survey Office.*) 8vo. Ottawa, 1899

Canadian Institute:
—— : Proceedings. New series. Vol. 1, No. 8.
(*Institute.*) 8vo. Toronto, 1899
—— : Transactions, Vol. 6, pt. 1, 2 (No. 11, 12).
(*Institute.*) 8vo. Toronto, 1899

Canada, Royal Society:
Proceedings and Transactions. Second series. Vol. 1, 1898.
(*Society.*) 8vo. Ottawa, 1898

Cape of Good Hope, Royal Observatory:
—— : Annals, vol. 2, pt. 2. Reference catalogue of Southern double stars, compiled by R. T. A. Innes.
(*Observatory.*) 4to. Edinburgh, 1899
—— : A catalogue of 3007 stars for the equinox 1890·0, from observations made . . . during the years 1885 to 1895, under the direction of David Gill . . . with appendices.
(*Observatory.*) 4to. London, 1898

Cape of Good Hope, Royal Observatory—*continued.*

—— : Catalogue of 2798 Zodiacal Stars for the epoch 1900, arranged for differential observations of the planets . . . selected and compiled under the direction of David Gill.
(*Observatory.*) 8vo. London, 1899

—— : Independent day numbers for the year 1901.
(*Observatory.*) 8vo. London, 1898

—— : Report of H.M. Astronomer . . . for the year 1898.
(*Observatory.*) 4to. London, 1899

Cape Town, South African Philosophical Society:
Transactions, 1898. Vol. 10, pt. 2, 3.
(*Society.*) 8vo. Cape Town, 1899

Cardiff, Astronomical Society of Wales:
The Cambrian Natural Observer. New series. Vol. 2, No. 3—Vol. 3, No. 1.
(*Society.*) 16mo. Cardiff, 1899–1900

Catania, Società degli Spettroscopisti Italiani:
Memorie . . . raccolte e pubblicate per cura del Prof. A. Riccò. Vol. 28, No. 4—Vol. 29, No. 3.
(*Society.*) 4to. Catania, 1899–1900

Chambers (George Frederick):
The Story of Eclipses simply told for general readers; with special reference to the total eclipse of the Sun of May 28, 1900.
(*The Publishers.*) 8vo. London, 1899

Chandler (Seth C.):
*Comparison of the observed and predicted motions of the pole, 1890–98, and determination of revised elements.
(*Author.*) 4to Boston, 1898

Chicago Academy of Sciences:
40th Annual Report, 1897.
(*Academy.*) 8vo. Chicago, 1898

Ciel et Terre. Revue populaire d'astronomie, de météorologie et de physique du globe. Année 20, No. 8—Année 21, No. 6.
(*Turnor and Horrox Fund.*) 8vo. Bruxelles, 1899–1900

Cincinnati Observatory:
Publications, No. 14.
(*Observatory.*) 4to. Cincinnati, 1898

J. G. Porter. Catalogue of 2030 stars for the epoch 1895, with an appendix giving the derivation of proper motion for 971 stars.

Ciscato (G.):

—— : *Osservazioni astronomiche fatte alla Specola di Padova nel 1896.
(*Observatory.*) 8vo. Venezia, 1897

—— : Determinazioni di latitudine e di azimut fatte alla Specola di Bologna nei mesi di giugno e luglio 1897. (R. Commissione Geodetica Italiana.)
(*Observatory.*) 4to. Venezia, 1899

Comets' tails no longer a mystery! and a few questions, by J. A. R.
(*Turnor and Horrox Fund.*) sq. 12mo. London, 1873

Copenhagen, Kongelige Danske Videnskabernes Selskab:
—— : Oversigt over det K. Danske Videnskabernes Selskabs Forhandlinger. 1899, No. 2–6; 1900, No. 1.
(*Society.*) 8vo. Kjöbenhavn, 1899–1900
—— : Skrifter, naturvidensk. og mathematisk Afd. 6te Række, Bd. 9, No. 1–3; Bd. 10, No. 1.
(*Society.*) 4to. Kjöbenhavn, 1898–1899

Cordoba, Oficina Meteorológica Argentina:
Anales . . . por su Director G. G. Davis. Tomo 12, parte 2.
(*The Office.*) 4to. Buenos Aires, 1898

Cortie (Aloysius L.):
*The November Meteors.
(*Author.*) 8vo. 1899

Cracow, Académie des Sciences:
Bulletin International: Comptes-rendus des séances, 1899, No. 5–10; 1900, No. 1–3.
(*Academy.*) 8vo. Cracovie, 1899–1900

Dijon, Académie des Sciences, Arts et Belles-lettres:
Mémoires, 4me série, Tome 6, 1897–98.
(*Academy.*) 8vo. Dijon, 1898

Downing (Arthur M. W.):
Precession tables adapted to Newcomb's value of the precessional constant, and reduced to the epoch 1910·0.
(*Author.*) 4to. Edinburgh, 1899

Dublin, Royal Irish Academy:
Proceedings, third series, Vol. 5, No. 3, 4.
(*Academy.*) 8vo. Dublin, 1899–1900

Dunér (Nils Christian):
*On the spectra of stars of class III. *b*.
(*Author.*) 8vo. Chicago, 1899

Earth Measured (The):
$\frac{b}{a} = \frac{20855447 \text{ ft.}}{20925890 \text{ ft.}}$; $= \frac{296 \cdot 06}{297 \cdot 06}$ and related quantities for Earth, Sun, Moon, and Jupiter, with comprehensive table. By a member of the Chicago Astronomical Society.
(*Author.*) 8vo. Chicago, 1899

English Mechanic (the) and World of Science:
Vol. 69–71 (No. 1786–1837).
(*Editor.*) fol. London, 1899–1900

Eredia (F.):
*Temperature di Catania e dell' Etna.
(*Author.*) 8vo. Catania, 1899

Europe, Association Géodésique Internationale:

—— : Comptes-rendus des séances de la douzième Conférence Générale . . . 1898.
(*Association.*) 4to. Berlin, 1899

—— : Tome 2, Rapport sur les triangulations . . . par le Général A. Ferrero.
(*Association.*) 4to. Florence, 1899

Fabry (Louis):

Recherches sur l'origine des comètes et les hypothèses cosmogoniques.
(*Author.*) 4to. Marseille, 1899

Fényi (Julius):

—— : *Protubérances du 8 août, 1896.
(*Author.*) 4to. Roma, 1896

—— : *The great sun-spot of September 1898.
(*Author.*) 8vo. Chicago, 1899

Flud (Robert):

Utriusque cosmi maioris scilicet et minoris metaphysica, physica atque technica historia . . . Tomus primus.
(*W. H. Wesley.*) fol. London, 1617–18

Ferguson (James):

Astronomy, explained upon Sir Isaac Newton's principles . . . with notes, and supplementary chapters, by David Brewster: second edition.
(*Turnor and Horrox Fund.*) 2 vols. 8vo., Edinburgh, 1821

Flammarion (Camille):

—— : Annuaire Astronomique et Météorologique pour 1900.
(*Editor.*) 8vo. Paris, 1899

—— : *Les éclipses du 20me siècle visibles à Paris.
(*Author.*) 8vo. Paris, 1899

Flammarion (Camille) et E. M. Antoniadi:

*Observations de l'aspect physique de Mars durant l'opposition de 1898–99.
(*Authors.*) 4to. Kiel, 1899

Foerster (Wilhelm):

Kalender und Uhren am Ende des Jahrhunderts.
(*Turnor and Horrox Fund.*) 8vo. Braunschweig, 1889

Franz (Julius):

*Die Figur des Mondes.
(*Author.*) fol. Königsberg, 1899

Galilei (Galileo):

Opere . . . Edizione Nazionale, sotto gli auspicii di Sua Maestà il Re d' Italia. Vol. 8, 9.
(*Italian Government.*) 4to. Firenze, 1898

Garavito (Julio):

Latitud del Observatorio di Bogotá (República de Colombia).
• (*Author.*) 4to. Bogotá, 1897

Gautier (Raoul):
Rapport sur le Concours de réglage de chronomètres 1898, 1899.
(*Author.*) 8vo. Genève, 1899–1900

Geminus:
Γεμινου εισαγωγη εις τα Φαινομενα. Gemini elementa astronomiae, ad codicum fidem recensuit, germanica interpretatione et commentariis instruxit C. Manitius.
(*Turnor and Horrox Fund.*) 8vo. Lipsiae, 1898

Geneva, Observatoire:
*Résumé météorologique . . . pour Genève et le Grand Saint-Bernard, par R. Gautier, 1897–98.
(*Observatory.*) 8vo. Genève, 1898–99

Georgetown College Observatory:
Sun-spot drawings made . . . in 1850 September 20 to November 6, by Benedict Sestini.
(*Observatory.*) 4to. Washington, 1898

Ginzel (F. K.):
—— : *Bemerkungen über den Werth der alten historischen Sonnenfinsternisse für die Mondtheorie.
(*Author.*) 4to. Kiel, 1899
—— : Spezieller Kanon der Sonnen- und Mondfinsternisse für das Ländergebiet der klassischen Altertumswissenschaften und den Zeitraum von 900 vor Chr. bis 600 nach Chr.
(*Author.*) 4to. Berlin, 1899

Glasenapp (Sergius de):
Mesures micrométriques d'étoiles doubles faites à Domkino et à St.-Pétersbourg. (5me série des mesures d'étoiles doubles.)
(*Author.*) 4to. St.-Pétersbourg, 1899

Goedseels (E.):
*Note sur la décimalisation des mesures angulaires et horaires. Tables de réduction.
(*Author.*) 8vo. Bruxelles, 1899

Göttingen, Königliche Akademie der Wissenschaften:
Nachrichten, mathematisch-physikalische Klasse. 1899 Heft 1–3.
(*Academy.*) 8vo. Göttingen, 1899

Greenwich, Royal Observatory:
—— : Astronomical and magnetical and meteorological observations made . . . 1897, under the direction of W. H. M. Christie.
(*Observatory.*) 4to. London, 1899
—— : Appendices :
Results of Astronomical Observations, 1897.
Results of Magnetical and Meteorological Observations, 1897.
Report of the Astronomer Royal to the Board of Visitors, 1900.

Hagen (J. G.):

—— : **Atlas stellarum variabilium. Series prima, complectens stellas variabiles intra limites declinationis −25° et 0°, quarum lux minima est infra magnitudinem 10^m.**
(*Turnor and Horrox Fund.*) 4to. Berolini, 1899

—— : Ditto. Series secunda . . . intra limites declinationis 0° et + 25°. . . .
(*Turnor and Horrox Fund.*) 4to. Berolini, 1899

Halifax, Nova Scotian Institute of Science:

Proceedings. Vol. 9. (Second series, Vol. 2.) pt. 4, 1897–98.
(*Institute.*) 8vo. Halifax, 1898

Halle, Kaiserliche Leopoldinisch-Carolinische deutsche Akademie der Naturforscher:

Abhandlungen (Nova Acta). Band 72, 74.
(*Academy.*) 4to. Halle, 1899

Hamburg, Sternwarte:

—— : *Beobachtungen von Cometen und kleinen Planeten . . . in den Jahren 1897–98.
(*Observatory.*) 4to. Kiel, 1899

—— : *Bericht . . . für 1897–98.
(*Observatory.*) 8vo. Hamburg, 1898

—— : Mittheilungen, No. 5.
(*Observatory.*) 8vo. Hamburg, 1899

R. Schorr. Bemerkungen und Berichtigungen zu Carl Rümker's Hamburger Stern-Catalogen. 2te Serie.

Hartwig (Ernst):

—— : *Ephemeriden veränderlicher Sterne für 1899, 1900.
(*Author.*) 8vo. Leipzig, 1898–99

—— : *Der veränderliche Stern vom Algoltypus Z Herculis.
(*Author.*) 8vo. Bamberg, 1900

Harvard College Astronomical Observatory:

—— : Annals, Vol. 23, pt. 2; Vol. 32, pt. 2; Vol. 33; Vol. 42, pt. 2; Vol. 44, pt. 1.
(*Observatory.*) 4to. Cambridge, Mass., 1899–1900.

Vol. 23, pt. 2. E. C. Pickering and O. C. Wendell. Discussion of Observations made with the Meridian Photometer.
Vol. 32, pt. 2. W. H. Pickering. Visual observations of the Moon and planets.
Vol. 33. Miscellaneous researches. 1894–99.
Vol. 42, pt. 2. Blue Hill meteorological observations.
Vol. 44, pt. 1. E. C. Pickering. Photometric revision of the Harvard Photometry, 1891–94.

—— : Circular, No. 44–50.
(*Observatory.*) 4to. Cambridge, Mass., 1899–1900

—— : Fifty-fourth annual report of the Director . . . 1898–99 By E. C. Pickering.
(*Observatory.*) 8vo. Cambridge, Mass., 1899

—— : Report of the Committee to visit the Observatory.
(*Observatory.*) 8vo. Cambridge, Mass., 1899

Hasselberg (B.):

—— : *On the wide cosmical dissemination of vanadium.
(*Author.*) 8vo. Chicago, 1899

—— : *Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen. V. Spectrum des Vanads.
(*Author.*) 4to. Stockholm, 1899

Helmert (F. R.):

*Neuere Fortschritte in der Erkenntniss der mathematischen Erdgestalt: Vortrag.
(*Author.*) 8vo. Leipzig, 1900

Helsingfors, Finska Vetenskaps Societet:

—— : Acta Societatis Scientiarum Fennicæ. Tomus 24.
(*Society.*) 4to. Helsingforsiae, 1899

—— : Öfversigt af Finska Vetenskaps-Societetens Förhandlinger, 41, 1898–99.
(*Society.*) 4to. Helsingfors, 1900

—— : Bidrag till kånnedom af Finlands natur och folk. Häftet 57.
(*Society.*) 8vo. Helsingfors, 1898

Henderson (Andrew):

The Coats Observatory, Paisley; its history and equipment.
(*Author.*) 8vo. Paisley, 1899

Hill (George William):

*On the extension of Delaunay's method in the Lunar Theory to the general problem of planetary motion.
(*Author.*) 8vo. New York, 1900

Himmel und Erde. Illustrierte naturwissenschaftliche Monatsschrift, herausgegeben von der Gesellschaft Urania; Redacteur P. Schwahn. Jahrgang 11, No. 9—Jahrgang 12, No. 8.
(*Editor.*) 8vo. Berlin, 1899–1900

Holden (Edward Singleton):

*The teaching of astronomy. (Report.)
(*Author.*) 8vo. Washington, 1899

Hong Kong Observatory:

Observations and researches made . . . in the year 1898, by W. Doberck.
(*Observatory.*) fol. Hong Kong, 1899

Horological Journal (the):

Vol. 41, 42. (No. 491–502).
(*Brit. Horol. Institute.*) 8vo. London, 1899–1900

Horton-Smith (Lionel):

Galileo . . . . versi Latini presentati alla R. Accademia . . . . in Padova, dal A. Favaro.
(*Author.*) 8vo. Padova, 1899

(Huggins, Sir William and Lady):
An atlas of representative stellar spectra from λ4870 to λ3300, together with a discussion of the evolutional order of the stars, and the interpretation of their spectra; preceded by a short history of the Observatory and its work. (Publications of Sir William Huggins's Observatory, vol. 1.)
(*Authors.*) fol. London, 1899

Huygens (Christiaan):
Œuvres complètes . . . . publiées par la Société Hollandaise des Sciences. Tome 8. Correspondance, 1676–1684.
(*Turnor and Horrox Fund.*) 4to. La Haye, 1899

India, Survey Department:
General report on the operations of the Survey of India Department . . . during 1897–98.
(*H.M. Govt. in India.*) fol. Calcutta, 1899

Indian Engineering:
An illustrated weekly journal, edited by Pat. Doyle. Vol. 25, No. 20—Vol. 27, No. 19.
(*Editor.*) fol. Calcutta, 1899–1900

Inwood's Tables of interest and mortality for the purchasing of estates and valuation of properties . . . . 25th edition, revised and extended by W. Schooling. With logarithms of natural numbers.
(*Editor.*) 8vo. London, 1899

Jenkins (B. J.):
The British weather chart, 1900.
(*M. C. Sharp.*) One sheet.

Jomard:
*Examen d'une opinion nouvelle sur le zodiaque circulaire de Dendera.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1822

Kasan, Imperial University:
Uchenuiya Zapiski. 1899, No. 5, 6.
(*University.*) 8vo. Kasan, 1899

Kestel (R. W. C.):
Radiant energy as a working power in the mechanism of the universe.
(*Author.*) 8vo. Port Adelaide, 1898

Kiel, Königliche Sternwarte:
Publicationen 10.
(*Observatory.*) 4to. Leipzig, 1899
P. Harzer. Ueber die Zeitbestimmung im Verticale des Polsternes.

Kinns (Samuel):
"Six Hundred Years."
(*Author.*) 8vo. London, 1898

Klein (Hermann J.):
Jahrbuch für Astronomie und Geophysik. Jahrgang 9, 1898.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1899

Klinkerfues (W.):
Theoretische Astronomie. Zweite . . . . . Auflage, von H. Buchholz.
(*Turnor and Horrox Fund.*) 4to. Braunschweig, 1899

Knowledge. An illustrated magazine of science, literature, and art. Vol. 22, 23 (No. 166–176).
(*Turnor and Horrox Fund.*) 4to. London, 1899–1900

Königsberg, Königliche Universitäts-Sternwarte:
Astronomische Beobachtungen . . . herausgegeben von H. Struve. Abtheilung 18, 19.
(*Observatory.*) fol. Königsberg, 1899

Kugler (Franz Xaver):
Die Babylonische Mondrechnung. Zwei Systeme der Chaldäer über den Lauf des Mondes und der Sonne . . . mit einem Anhang über Chaldäische Planetentafeln.
(*Author.*) 8vo. Freiburg im Breisgau, 1900

Lais (Giuseppe):
Tre nebulose fotografate recentemente alla Specola Vaticana.
(*Author.*) 4to. Roma, 1899

Lebon (Ernest):
Histoire abrégée de l'Astronomie.
(*Author.*) 8vo. Paris, 1899

Leeds Astronomical Society:
Report (Journal) and Transactions, 1894, 1897–98.
(*Society.*) 8vo. Leeds, 1895–99

Leipzig, Astronomische Gesellschaft:
Vierteljahrsschrift, Jahrgang 34; Jahrgang 35, Heft 1.
(*Society.*) 8vo. Leipzig, 1899–1900

Leipzig, Königlich Sächsische Gesellschaft der Wissenschaften:
——: Abhandlungen, mathematisch-physische Classe. Band 25, No. 3—Band 26, No. 2.
(*Society.*) 8vo. Leipzig, 1899–1900
——: Berichte über die Verhandlungen: mathematisch-physische Classe, 1899–1900. Band 51, Heft 3—Band 52, Heft 1.
(*Society.*) 8vo. Leipzig, 1899–1900

Lindemann (Ferdinand):
Gedächtnissrede auf Philipp Ludwig von Seidel.
(*Munich Academy.*) 4to. München, 1898

Lisbon, Real Observatorio Astronomico:
O eclipse de Sol de 1900 Maio 28 em Portugal.
(*Observatory.*) 4to. Lisboa, 1900

Liverpool Literary and Philosophical Society:
Proceedings . . . 88th session, 1898–99.
(*Society.*) 8vo. Liverpool, 1899

London, British Astronomical Association:
—— : Journal, Vol. 9, No. 7—Vol. 10, No. 7.
(*Association.*) 8vo. London, 1899–1900
—— : Memoirs, Vol. 7, pt. 4; Vol. 8, pt. 1–3; Vol. 9, pt. 1.
(*Association.*) 8vo. London, 1899–1900
—— : List of members, 1899. 8vo. London, 1899
—— : The Indian Eclipse, 1898. Report of the expedition organised by the British Astronomical Association to observe the total Solar Eclipse of 1898 January 22. Edited by E. Walter Maunder.
(*Association.*) 8vo. London, 1899

London, Camera Club:
Journal, Vol. 13–14 (No. 158–169).
(*The Club.*) 4to. London, 1899–1900

London, Geological Society:
—— : Quarterly Journal, Vol. 55, pt. 3—Vol. 56, pt. 1 (No. 219–221).
(*Society.*) 8vo. London, 1899–1900
—— : List of Fellows. 8vo. London, 1899

London, Meteorological Office:
—— : Hourly means of the readings obtained from the self-recording instruments at the five Observatories under the Meteorological Council, 1895–96.
(*The Office.*) 4to. London, 1899
—— : Meteorological Observations at stations of the second order for the years 1895–96.
(*The Office.*) 4to. London, 1899
—— : The diurnal range of rain at the seven observatories in connection with the Meteorological Office, 1871–90. By R. H. Scott.
(*The Office.*) 8vo. London, 1900
—— : Weekly weather report, Vol. 16, No. 23—Vol. 17, No. 22.
(*The Office.*) 4to. London, 1899–1900

London, Nautical Almanac and Astronomical Ephemeris for the meridian of the Royal Observatory, Greenwich. 1903.
(*Lords Commissioners of Admiralty.*) 8vo. London, 1900
—— : Ditto, Part 1; containing such portions as are essential for navigation.
(*Lords Commissioners of Admiralty.*) 8vo. London, 1900

London, Physical Society:
Proceedings, Vol. 16, pt. 6—Vol. 17, pt. 1.
(*Society.*) 8vo. London, 1899–1900

London, Royal Geographical Society:
The Geographical Journal, including the Proceedings of the Royal Geographical Society. Vol. 13, No. 7—Vol. 15, No. 6.
(*Society.*) 8vo. London, 1899-1900

London, Royal Institution:
Proceedings, 1898. Vol. 15, pt. 3 (No. 92).
(*Institution.*) 8vo. London, 1899

London, Royal Meteorological Society:
—— : Quarterly Journal, Vol. 25 (No. 110-112).
(*Society.*) 8vo. London, 1899-1900
——: The Meteorological Record: Monthly results of observations made at the stations of the Royal Meteorological Society, with remarks on the weather . . . by W. Marriott. Vol. 18, 19 (No. 72-73).
(*Society.*) 8vo. London, 1899-1900

London, Royal Photographic Society:
The Photographic Journal; including the Transactions of the Royal Photographic Society, Vol. 23, No. 10—Vol. 24, No. 8.
(*Society.*) 8vo. London, 1899-1900

London, Royal Society:
—— : Proceedings, Vol. 65-66 (No. 415-429).
(*Society.*) 8vo. London, 1899-1900
—— : List of Fellows, 1898.
(*Society.*) 4to. London
—— : Report of the Meteorological Council for the year ending 31st March, 1899.
(*Society.*) 8vo. London, 1899

London, Royal United Service Institution:
Journal, Vol. 43, 44 (No. 256-267).
(*Institution.*) 8vo. London, 1899-1900

London, Society of Arts:
Journal, Vol. 47, 48 (No. 2429-2481).
(*Society.*) 8vo. London, 1899-1900

London, University College:
Calendar, session 1899-1900.
(*The College.*) 8vo. London, 1899

Lorenzoni (G.):
*L'effetto della flessione del pendolo sul tempo della sua oscillazione.
(*Observatory.*) 8vo. Venezia, 1897

Lund, Astronomiska Observatorium:
—— : *Meddelanden . . . No. 4-9.
(*Observatory.*) 8vo. Stockholm, 1899
—— : Observations des étoiles de la zone entre 35° et 40° de déclinaison boréale . . . réduites à l'équinoxe moyen de 1875·0, par N. C. Dunér et Folke Engström. Tome 3.
(*Observatory.*) 4to. Lund, 1900

Lynn (William Thynne):

—— : Remarkable Comets; a brief survey of the most interesting facts in the history of cometary astronomy. Eighth edition.
(*Author.*) 8vo. London, 1900

—— : Remarkable Eclipses; a sketch of the most interesting circumstances connected with the observation of solar and lunar eclipses both in ancient and modern times. Fifth edition.
(*Author.*) 8vo. London, 1900

Macrobius (Aurelius Theodosius):

Opera: accedunt integræ Isacii Pontani, Joh. Meursii, Jacobi Gronovii Notæ & Animadversiones.
(*Turnor and Horrox Fund.*) 8vo. Londini, 1694

Madras Observatory:

—— : Report . . . for the year 1898–99.
(*Observatory.*) fol. Madras, 1899

—— : Results of observations of the fixed stars made with the Madras meridian circle under the direction of the late N. R. Pogson, by C. Michie Smith. Vol. 9. General Catalogue.
(*Observatory.*) 4to. Madras, 1899

Madrid, Observatorio Astronómico:

—— : Memoria sobre el eclipse total de sol del dia 28 de Mayo de 1900.
(*Observatory.*) 4to. Madrid, 1899

—— : Observaciones meteorológicas efectuadas . . . 1896–97.
(*Observatory.*) 8vo. Madrid, 1899

—— : Resumen de las observaciones meteorológicas efectuadas en la Península [etc.], 1895–96.
(*Observatory.*) 8vo. Madrid, 1899

—— : Maps of Spain, etc., showing paths of total solar eclipses of 1900 and 1905.
(*Prof. V. Ventosa.*) Madrid

Manchester Literary and Philosophical Society:

Memoirs and Proceedings, Vol. 43, pt. 2—Vol. 44, pt. 3.
(*Society.*) 8vo. Manchester, 1899–1900

Manila, Observatorio:

—— : Baguios o ciclones Filipinos: Estudio teórico-práctico, par J. Algué.
(*Observatory.*) 4to. Manila, 1897

—— : Boletín Mensual, 1897, No. 9–12: 1898, 1 trimestre.
(*Observatory.*) 4to. Manila, 1897–99

—— : La erupción del Volcán Mayón . . . 1897, por J. Coronas.
(*Observatory.*) 4to. Manila, 1898

—— : Las nubes en el Archipiélago Filipino, por J. Algué. 1895–97.
(*Observatory.*) 4to. Manila, 1899

Manila, Observatorio—*continued.*

—— : The Baro-Cyclono-Meter.
(*Observatory.*) 8vo. Manila, 1898

—— : Tifones del Archipiélago Filipino y mares circunvecinos, 1895 y 1896 ; por J. Doyle.
(*Observatory.*) 4to. Manila, 1899

Mascari (A.) :

—— : *Sulla frequenza e distribuzione in latitudine delle macchie solari osservate al R. Osservatorio Astrofisico di Catania nel 1898.
(*Author.*) 4to. Catania, 1899

—— : *Sulle protuberanze solari osservate al R. Osservatorio di Catania nell' anno 1898.
(*Author.*) 4to. Catania, 1899

Mauritius, Royal Alfred Observatory :

—— : Annual Report of the Director . . for the year 1898.
(*Observatory.*) fol. Mauritius, 1899

—— : Mauritius magnetical reductions . . . being a discussion of the results obtained . . . from 1875 to 1890, under the direction of C. Meldrum, together with a discussion of the absolute determinations of the magnetic declination, horizontal force, and dip from 1875 to 1897. By T. F. Claxton.
(*Observatory.*) fol. Mauritius, 1899

—— : Results of magnetical and meteorological observations made . . . in the year 1897 under the direction of T. F. Claxton.
(*Observatory.*) fol. Mauritius, 1899

Mee (Arthur B. P.) :

The heavens at a glance, 1900 [Sheet Calendar].
(*Author.*) Cardiff, 1899

Melbourne Observatory :

—— : Record of results of observations in meteorology and terrestrial magnetism, . . . 1898–99, under the direction of P. Baracchi.
(*Observatory.*) 8vo. Melbourne, 1899

—— : Report of the Board of Visitors, . . . together with the report of the Government Astronomer, 1898–99.
(*Observatory.*) fol. Melbourne, 1899

Milan, Reale Osservatorio di Brera :

Pubblicazioni, No. 40, parte 3.
(*Observatory.*) 4to. Milano, 1899

Al-Battānī sive Albatenii Opus astronomicum . . . textum Arabicum continens. C. A. Nallino.

Millosevich (Elia) :

—— : *Sull' orbito del pianeta Eros.
(*Author.*) 4to. Roma, 1899

—— : *Sull' orbito di (433) Eros in base alle osservazioni degli anni 1898–99.
(*Author.*) 4to. Kiel, 1899

Moncalieri, Osservatorio Centrale del Real Collegio Carlo Alberto:

—— : Annuario Storico meteorologico Italiano; redatto di G. Boffito e P. Maffi. Vol. 2, 1899.
(*Editors.*) 8vo. Torino, 1900

—— : Bollettino mensuale (Società Meteorologica Italiana). Serie 2, Vol. 19, Nos. 4–12.
(*Observatory.*) 4to. Torino, 1899–1900

Montevideo, Institut solaire International:

—— : Éclipses du soleil intérieur.
(*Institute.*) 4to. Montévidéo, 1900

—— : Le Soleil intérieur: communication scientifique.
(*Institute.*) 4to. Montévidéo, 1900

Montpellier, Académie des Sciences et Lettres:

Mémoires de la section des sciences. 2me serie, Tome 2, No. 5.
(*Academy.*) 8vo. Montpellier, 1898

Moscow, Société Impériale des Naturalistes:

Bulletin, Année 1898, No. 4; Année 1899, No. 3.
(*Society.*) 8vo. Moscou, 1899–1900

Munich, Königlich bayerische Akademie der Wissenschaften:

—— : Abhandlungen der mathematisch-physikalischen Classe. Band 19, Abth. 3; Band 20, Abth. 1.
(*Academy.*) 4to. München, 1899

—— : Sitzungsberichte der mathematisch-physikalischen Classe. 1899, Heft 2.
(*Academy.*) 8vo. München, 1899

Naples, Società Reale (R. Accademia delle Scienze):

—— : Atti, serie seconda, vol. 9.
(*Academy.*) 4to. Napoli, 1899

—— : Rendiconto dell' Accademia delle scienze fisiche e matematiche: Serie 3. Vol. 5, fasc. 5—Vol. 6, fasc. 4. (Anno 38, 39.)
(*Academy.*) 8vo. Napoli, 1899–1900

Narrien (John):

Practical Astronomy and Geodesy, including the projections of the sphere and spherical trigonometry; for the use of the Royal Military College.
(*Turnor and Horrox Fund.*) 8vo. London, 1845

Natal Observatory:

Report of the Government Astronomer for the year 1898.
(*Observatory.*) fol. Pietermaritzburg, 1899

Nature. A weekly illustrated journal of science, Vol. 60–62 (No. 1546–1597).
(*Turnor and Horrox Fund.*) 4to. London, 1899–1900

Naturwissenschaftliche Rundschau. Wöchentlicher Bericht über die Fortschritte auf dem Gesammtgebiete der Naturwissenschaften . . . herausgegeben von W. Sklarek. Jahrgang 14, No. 24—Jahrgang 15, No. 23.
(*Editor.*) 4to. Braunschweig, 1898–99

New Haven, Connecticut Academy of Arts and Sciences:
Transactions, Vol. 10, pt. 1.
(*Academy.*) 8vo. New Haven, 1899

Nice, Observatoire (fondation R. Bischoffsheim):
Annales . . . publiées sous les auspices du Bureau des Longitudes, par M. Perrotin. Tome 1.
(*M. Bischoffsheim.*) 4to. Paris (Atlas fol.), 1899

Nichol (John Pringle):
The planetary system; its order and physical structure.
(*Turnor and Horrox Fund.*) 8vo. London, 1850

Niesten (L.):
Bulletin mensuel du magnétisme terrestre de l'Observatoire Royal de Belgique, Jan.–Oct., 1899; Jan.–Fév., 1900 (Année 1 et 2).
(*Editor.*) 8vo. Bruxelles, 1899–1900

Nobile (A.):
*Appunti sul moto del Sole fra le altre stelle.
(*Author.*) 8vo. Napoli, 1897

Norwegian North Atlantic Expedition, 1876–78:
Nos. 25–27. Zoologi.
(*Norwegian Government.*) 4to. Christiania, 1899–1900

Observatory (The). A monthly review of astronomy; edited by T. Lewis and H. P. Hollis, Vol. 22–23 (No. 281–293).
(*Editors.*) 8vo. London, 1899–1900

Ó-Gyalla, Astrophysikalisches und Meteorologisches Observatorium:
Beobachtungen . . . von Nicolas von Konkoly; enthaltend Beobachtungen 1896–98. Band 19–21. Neue Folge, Band 2.
(*Observatory.*) 4to. Budapest, 1899

Ó-Gyalla, Königl. ung. meteorologisch-magnetisches Central-Observatorium:
Beobachtungen angestellt Mai 1899–April 1900.
(*Observatory.*) 4to. Budapest, 1899–1900

Olbers, (Wilhelm):
——: Sein Leben und seine Werke . . . herausgegeben von C. Schilling. Band 2. Briefwechsel zwischen Olbers und Bessel.
(*Turnor and Horrox Fund.*) 8vo. Berlin, 1900

Olbers, (Wilhelm)—*continued.*
—— : Wilhelm Olbers' Leben und Werke. Ergänzungsband. Neue Reduktion der . . . im Zeitraum 1795 bis 1831 auf seiner Sternwarte in Bremen angestellten Beobachtungen von Kometen und kleinen Planeten . . . Berechnet von W. Schur und A. Stichtenoth.
(*Prof. Schur.*) 8vo. Berlin, 1899

Otti (Hans):
Eigenschaften der Bessel'schen Funktionen zweiter Art. Inaugural-Dissertation.
(*Berne University.*) 8vo. Berne, 1899

Oxford, Radcliffe Observatory:
Astronomical and Meteorological Observations made . . . in the years 1890–91, under the superintendence of E. J. Stone. Edited by A. A. Rambaut.
(*Observatory.*) 4to. Oxford, 1899

Oxford University Observatory:
Twenty-fourth and twenty-fifth Annual Reports of the Savilian Professor . . . for 1898–1900.
(*Observatory.*) 8vo. Oxford, 1899–1900

Paganus (Giovanni Battista):
Metodo di computare i tempi . . . divisa in due parti; nella prima si contiene il metodo di computare i tempi giusta la forma dell' anno nuovo Gregoriano: nella seconda il metodo di computare giusta la forma dell' anno vecchio, che dicono Giuliano.
(*Turnor and Horrox Fund.*) 4to. Palermo, 1726

Paris, Académie des Sciences:
Comptes-rendus hebdomadaires des séances. Tome 128, No. 23—Tome 130, No. 22.
(*Academy.*) 4to. Paris, 1899–1900

Paris, Bureau des Longitudes:
—— : Annuaire pour l'an 1900. Avec des notices scientifiques.
(*The Bureau.*) 16mo. Paris [1899]
—— : Connaissance des Temps, ou des mouvements célestes pour le méridien de Paris, à l'usage des astronomes et des navigateurs, 1901.
(*The Bureau.*) 8vo. Paris, 1898
—— : Ditto. Extrait à l'usage des Écoles d'Hydrographie et des marins du commerce, 1900.
(*The Bureau.*) 8vo. Paris, 1898

Paris, Bureau International des Poids et Mesures:
—— : Procès-verbaux des séances [du comité] de 1899.
(*Bureau.*) 8vo. Paris, 1899
—— : Travaux et Mémoires. Tome 9.
(*Bureau.*) 4to. Paris, 1898

Paris, Dépôt Général de la Marine:
Annales Hydrographiques. Série 2. Année 1899.
(*Depôt of Marine.*) 8vo. Paris, 1900

Paris, Observatoire:
——: Annales . . . publiées sous la direction de M. Lœwy. Observations, 1900.
(*Observatory.*) 4to. Paris, 1900
——: Carte photographique du ciel, par Paul et Prosper Henry. Zone +24°. [Forty-three charts.]
(*Observatory.*)
——: Rapport annuel sur l'état de l'Observatoire, 1898, par M. Lœwy.
(*Observatory.*) 4to. Paris, 1899

Paris, Société Astronomique de France:
Bulletin . . . et revue mensuelle d'astronomie, de météorologie et de physique du globe, 1899–1900. Année 13, No. 6—Année 14, No. 5.
(*Society.*) 8vo. Paris, 1899–1900

Paris, Société Mathématique de France:
Bulletin. Tome 27, Fasc. 2—tome 28, Fasc. 2.
(*Society.*) 8vo. Paris, 1899–1900

Paris, Société Philomathique:
Bulletin. 9me série. Tome 1, Nos. 1–4.
(*Society.*) 8vo. Paris, 1898-99

Perth Observatory, Western Australia:
Meteorological Observations made at the Perth Observatory and other places in Western Australia . . . 1897–98, under the direction of W. E. Cooke.
(*Observatory.*) fol. Perth, 1898–99

Philadelphia, American Philosophical Society:
——: Proceedings, Vol. 37, No. 159, 160.
(*Society.*) 8vo. Philadelphia, 1899
——: Transactions, new series, Vol. 20, pt. 1.
(*Society.*) 4to. Philadelphia, 1899

Philadelphia, Franklin Institute:
Journal, years 74, 75. Vol. 147, No. 6—Vol. 149, No. 5.
(*Institute.*) 8vo. Philadelphia, 1899–1900

Philadelphia, University of Pennsylvannia:
Publications: series in astronomy. Vol. 1, pt. 2. Results of Observations with the zenith telescope of the Flower Astronomical Observatory, 1896–98. By C. L. Doolittle.
(*Observatory.*) 4to. Philadelphia, 1899

Philosophical Magazine:
The London, Edinburgh, and Dublin Philosophical Magazine. Series 5. Vol. 48, 49. (No. 290–301.)
(*Turnor and Horrox Fund.*) 8vo. London, 1899–1900

Pola, Hydrographisches Amt der K. und K. Kriegs-Marine:
Meteorologische Termin-Beobachtungen in Pola, Sebenico und Teodo, April 1899–März 1900.
(*The Office.*) obl. fol. Wien, 1899–1900

Popular Astronomy. Edited by W. W. Payne and H. C. Wilson. Vol. 7, 8. (No. 66–76.)
(*Editors.*) 8vo. Northfield, Minn., 1899–1900

Potsdam, Astrophysikalisches Observatorium:
Feier zur Einweihung des neuen Kuppelbaus und des grossen Refractors . . . am 26 August, 1899
(*Observatory.*) 4to. Potsdam, 1899

Potsdam, Königl. preussisches Geodätisches Institut; und Centralbureau der Internationalen Erdmessung:
——: Jahresbericht des Direktors, 1898–99.
(*The Institute.*) 8vo. Potsdam, 1899
——: Veröffentlichung, Neue Folge, No. 1.
(*The Institute.*) 4to. Berlin, 1900
Die Polhöhe von Potsdam. II.

Prague, K.K. Sternwarte:
Magnetische und meteorologische Beobachtungen im Jahre 1898. Jahrgang 59 . . . herausgegeben von L. Weinek.
(*Observatory.*) 4to. Prag, 1899

Prinz (W.):
* L'échelle réduite des expériences géologiques permet-elle leur application aux phénomènes de la nature? Exemples: Les figures de percussion et de contraction, etc., les cirques volcaniques terrestres et lunaires. (2me. article.)
(*Author.*) 8vo. Bruxelles, 1899

Prud'homme (Louis):
Le ciel pour tous, ou étude méthodique des mondes célestes; formant un traité d' astronomie à la portée de tout le monde.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1898

Pulkowa, Observatoire Central Nicolas:
Die Odessaer Abtheilung der Nicolai-Hauptsternwarte.
(*Observatory.*) 8vo. St. Petersburg, 1899

(Queensland):
International catalogue of scientific literature. Queensland volume. By J. Shirley.
(*Queensland Govt.*) 8vo. Brisbane, 1899

Rambaut (Arthur A.):
* On the orbit of the part of the Leonid stream which the earth encountered on the morning of 1898 November 15.
(*Author.*) 8vo. London, 1899

Rand (Cater):
Description and use of the patent military and naval telescope for measuring distances and the extension of objects at sight.
(*Turnor and Horrox Fund.*) 8vo. London [1799]

Riccò (Annibale):
* Riassunto della sismografia del terremoto Calabro-Siculo del 16 novembre, 1894.
(*Author.*) 4to. Roma, 1899

Riccò (Annibale), T. Zona, e G. Saija:
* Calcolo preliminare della differenza di longitudine tra Catania e Palermo, e determinazione delle anomalie di gravità in Catania.
(*Prof. Riccò*). 4to. Catania, 1899

Rice (Herbert L.):
The theory and practice of Interpolation; including mechanical quadrature, and other important problems concerned with the tabular values of functions: with the requisite tables.
(*Author.*) 4to. Lynn, Mass., 1899

Rio de Janeiro, Observatorio:
——: Annuario . . . para o anno de 1899.
(*Observatory.*) 8vo. Rio de Janeiro, 1899
——: Boletim mensal. 1900, 1, 2.
(*Observatory.*) 4to. Rio de Janeiro, 1900

Roberts (Isaac:
Photographs of stars, star-clusters, and nebulæ, together with records of results obtained in the pursuit of celestial photography. Vol. 2.
(*Author.*) 4to. London [1900]

Rome, Accademia Pontificia de' nuovi Lincei:
Atti . . . Anno 52, sessione 3–5: Anno 53, sess. 1–3.
(*Academy.*) 4to. Roma, 1899–1900.

Rome, Reale Accademia dei Lincei:
Atti . . . Anno 296, 297 (1899–1900), Serie quinta. Rendiconti. Classe di scienze fisiche, matematiche e naturali. Vol. 8, semestre 1, fasc. 10—Vol. 9, semestre 1, fasc. 9.
(*Academy.*) 4to. Roma, 1899–1900

Rome, Società degli Spettroscopisti Italiani.—*See* CATANIA.

Rousdon Observatory, Devon:
Variable star notes. No. 2–6. Sir C. E. Peek.
(*Sir C. E. Peek.*) obl. 8vo. 1897–99.

Rubin (Tryggve):
* Meteoren den 25 November, 1897.
(*Upsala Observatory.*) 8vo. Stockholm, 1898

Rugby School Natural History Society:
Report . . . for the years 1898 and 1899.
(*Rugby School.*) 8vo. Rugby, 1899–1900

St. Petersburg, Académie Impériale des Sciences:
Bulletin, série 5. Tome 8, No. 5—Tome 10, No. 4.
(*Academy.*) 4to. St.-Pétersbourg, 1898–99

St. Petersburg, Société Astronomique Russe:
Ephémérides des étoiles (W. Döllen) pour la détermination de l'heure et de l'azimut au moyen d'un instrument des passages portatif établi dans le plan vertical de la polaire, pour 1900.
(*Society.*) 8vo. St.-Pétersbourg, 1899

San Fernando, Instituto y Observatorio de Marina:
——: Almanaque Náutico para el año 1901.
(*Observatory.*) 4to. San Fernando, 1899
——: Anales . . . publicados por órden de la superioridad por el Director D. Juan Viniegra. Sección 1. Observaciones astronomicas, año 1893.
(*Observatory.*) 4to. San Fernando, 1899

San Francisco, Astronomical Society of the Pacific:
Publications, Vol. 11–12 (No. 68–73).
(*Society.*) 8vo. San Francisco, 1899–1900

Scarborough Observatory:
Report . . . for the year 1898. By E. W. Ellerbeck.
(*Observatory.*) 4to. Scarborough, 1899

Scheiner (Julius):
Strahlung und Temperatur der Sonne.
(*Turnor and Horrox Fund.*) 8vo. Leipzig, 1899

Schiaparelli (Giovanni Virginio):
* Osservazioni astronomiche e fisiche sulla topografia e costituzione del pianeta Marte, fatte nel Specola Reale di Brera in Milano . . . durante l' opposizione del 1888.
(*Author.*) 4to. Roma, 1899

Schmidt (Frid. Sam.):
Dissertatio de Zodiaci nostri origine Ægyptia.
(*Turnor and Horrox Fund.*) 8vo. Bernæ, 1760

Schobloch (Anton):
* Bahnbestimmung des Kometen 1847 V. (Brorsen).
(*Author.*) 4to. Wien, 1898

Schupmann (L.):
Die Medial-Fernrohre: eine neue Konstruktion für grosse astronomische Instrumente.
(*Author.*) 8vo. Leipzig, 1899

Schur (Wilhelm):
* Ernst Schering (Nekrolog).
(*Author.*) 8vo. Leipzig, 1898

See (Thomas Jefferson Jackson):
* On the temperature of the Sun and on the relative ages of the stars and nebulæ.
(*Author.*) 8vo. St. Louis, Mo., 1900

Seeliger (Hugo):
——: * Ueber die Vertheilung der nach einer Ausgleichung übrig bleibenden Fehler.
(*Author.*) 8vo. München, 1899
——: * Zur Vertheilung der Fixsterne am Himmel.
(*Author.*) 8vo. München, 1900

Serviss (Garrett P.):
Astronomy with an opera-glass: a popular introduction to the study of the starry heavens with the simplest optical means. 8th edition with appendix.
(*Turnor and Horrox Fund.*)
8vo. New York and London, 1896

Sestini (Benedict):
Sun-spot drawings made at the Georgetown College Observatory in 1850 September 20 to November 6.
(*Observatory.*) 4to. Washington, 1898

Sirius: Zeitschrift für populäre Astronomie; Redakteur H. J. Klein. Band 32, Heft 7—Band 33, Heft 6.
(*Editor.*) 8vo. Leipzig, 1899–1900

Slugg (J. T.):
Observational astronomy and guide to the use of the telescope . . . edited by J. T. S.
(*Turnor and Horrox Fund.*) 8vo. Manchester [1862].

Società Meteorologica Italiana:
Atti del iv. Congresso Meteorologico Italiano . . . 1898.
(*Society.*) 8vo. Torino, 1899

Southport, Fernley Observatory:
Report and results of [meteorological] observations for the year 1899, by J. Baxendell. . .
(*Author.*) 4to. Southport, 1900

Stockholm, Kongliga Svenska Vetenskaps Akademie:
——: Bihang till . . . Handlingar. Afdelning 1, Mathematik, Astronomi [&c.]. Bandet 24.
(*Academy.*) 8vo. Stockholm, 1899
——: Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar, 1899. Årgången 56.
(*Academy.*) 8vo. Stockholm, 1899

Stonyhurst College Observatory:
Results of meteorological and magnetical observations, with report and notes of the director, Rev. W. Sidgreaves. 1899.
(*Observatory.*) 8vo. Clitheroe, 1900

Strassburg, Kaiserliche Universitäts-Sternwarte:
Annalen . . . . herausgegeben von E. Becker. Band 2.
(*Observatory.*) 4to. Karlsruhe, 1899

wartz, (—):
Le Zodiaque expliqué, ou recherches sur l'origine et la signification des constellations de la sphère grecque.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1809

wift (Lewis):
*Simple lessons in Astronomy.
(*Author.*) 8vo. Rochester, N.Y., 1890

ydney, Royal Society of New South Wales:
Journal and Proceedings for 1898. Vol. 32.
(*Society.*) 8vo. Sydney, 1898

acubaya, Observatorio Astronómico Nacional:
— : Anuario . . . . para el año de 1900. A. Anguiano. Año 20.
(*Observatory.*) 8vo. México, 1899
— : Boletín, Tomo 2, No. 5.
(*Observatory.*) 4to. México, 1899
— : Observaciones meteorológicas . . . . 1895.
(*Observatory.*) fol. México, 1897

arleton (Francis A.):
An introduction to the mathematical theory of attraction.
(*Turnor and Horrox Fund.*) 8vo. London, 1899

ebbutt (John):
Report of Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales, for the year 1899.
(*Author.*) 8vo. Sydney, 1900

eramo, Osservatorio privato di Collurania:
Pubblicazioni, No. 2.
(*Observatory.*) 8vo. Collurania [Roma], 1900
G. Boccardi. Variazione della Latitudine di Collurania; Metodo di Tietjen per la correzione dell' orbita di un pianeta; applicazione del metodo.

hiele (T. N.):
*Resolution into series of the third band of the carbon band spectrum.
(*Author.*) 8vo. Chicago, 1898

homas (—):
Éloge de René Descartes : discours qui a remporté le prix de l'Académie Françoise en 1765.
(*Turnor and Horrox Fund.*) 8vo. Paris, 1765

'odd (David P.) and W. T. Lynn:
Stars and telescopes : a handbook of popular astronomy, founded on the 9th edition of Lynn's Celestial Motions.
(*W. T. Lynn.*) 8vo. Boston, 1899

'oronto, Astronomical and Physical Society:
Transactions . . . for the year 1899; including tenth Annual Report.
(*Society.*) 8vo. Toronto, 1900

Toronto, Canadian Institute:
—— : Proceedings, new series, Vol. 1, pt. 2, No. 8.
(*Institute.*) 8vo. Toronto, 1899
—— : Transactions. Vol. 6, pt. 1, 2 (No. 11, 12).
(*Institute.*) 8vo. Toronto, 1899

Toulouse, Observatoire Astronomique, Magnétique et météorologique:
Annales . . . . Tome 3 . . . sous la direction de B. Baillaud.
(*Observatory.*) 4to. Paris, 1899

Tringali (E.):
*Correzione dell' A.R. di ν Andromedæ della Connaissance des Temps per il 1900 e per gli anni precedenti.
(*Author.*) . 4to. Catania, 1899

Truro, Royal Institution of Cornwall:
Journal, Vol. 13, part 4. 1898.
(*Institution.*) 8vo. Truro, 1899

Turin, Osservatorio Astronomico della R. Università:
*Pubblicazioni, 1899.
(*Observatory.*) 8vo. Torino, 1899
L. Carnera. Le ore di sole rilevate a Torino mediante l'eliofanometro . . . . 1896–98.
V. Balbi. Osservazioni meteorologiche, 1898.
L. Carnera. „ „ 1899.
L. Gabba. Effemeridi del sole e della luna, 1900.

Turin, Reale Accademia delle Scienze:
—— : Atti, Vol. 34, No. 10—Vol. 35, No. 6.
(*Academy.*) 8vo. Torino, 1899–1900
—— : Memorie, Serie seconda. Tomo 49.
(*Academy.*) 4to. Torino, 1900

United States Coast and Geodetic Survey:
—— : Bulletin. No. 37–40.
(*Survey Office.*) 4to. Washington, 1899
—— : No. 40. Second edition.
(*Survey Office.*) 4to. Washington, 1900
—— : Report of the Superintendent . . . showing the progress of the work during the years 1896–97.
(*Survey Office.*) 4to. Washington, 1898

Upsala, Kongliga Vetenskaps Societet:
Nova Acta Regiæ Societatis Scientiarum Upsaliensis. Series 3, Vol. 18, fasc. 1.
(*Society.*) 4to. Upsaliæ, 1899

Valentiner (Wilhelm):
Handwörterbuch der Astronomie. Lieferung 18–20.
(*Turnor and Horrox Fund.*) 8vo. Breslau, 1899–1900

Very (Frank W.):
*Heliographic positions.
(*Author.*) 8vo. Chicago, 1898

Vienna, Kaiserliche Akademie der Wissenschaften:
—— : Denkschriften . . . Mathematisch-naturwissenschaftliche Classe. Band 65–67.
(*Academy.*) 4to. Wien, 1898–99
—— : Sitzungsberichte . . . Mathematisch-naturwissenschaftliche Classe. Abtheilung II.a., Mathematik, Astronomie, Physik, Meteorologie, Mechanik. Band 107, No. 3–10.
(*Academy.*) 8vo. Wien, 1898

Vienna, K. und K. Militär-geographisches Institut:
Astronomische-geodätische Arbeiten. Band 13–16. Astronomische Arbeiten.
(*Institute.*) 4to. Wien, 1899
Bd. 13. Trigonometrische Arbeiten.
14. Das Präcisions-Nivellement.
15. Trigonometrische Arbeiten.
16. Längenunterschied-Messungen, etc.

Vienna, K.K. Universitäts-Sternwarte:
Annalen . . . herausgegeben von E. Weiss. Band 13.
(*Observatory.*) 4to. Wien, 1898

Vienna, von Kuffner'sche Sternwarte:
Publicationen . . . herausgegeben von Leo de Ball. Band 5.
(*Herr von Kuffner.*) 4to. Wien, 1900

Vince (Samuel):
The elements of astronomy, designed for the use of students in the University. Fourth edition.
(*Turnor and Horrox Fund.*) 8vo. Cambridge, 1816

Vizagapatam, G. V. Juggarow Observatory:
—— : Notes on the meteorology of Vizagapatam. Part 2. Rainfall. By W. A. Bion.
(*Observatory.*) 8vo. Calcutta, 1899
—— : Report . . . including the results of observations for the year 1897.
(*Observatory.*) 8vo. Calcutta, 1899

Vogel (H. C.):
* Über die im letzten Decennium in der Bestimmung der Sternbewegungen in der Gesichtslinie erreichten Fortschritte.
(*Author.*) 4to. Berlin, 1900

Washington, Navy Department:
—— : The American Ephemeris and Nautical Almanac, 1900 (second edition), 1901, 1902.
(*American Ephemeris Office.*) 8vo. Washington, 1899–1900
—— : Supplement to American Ephemeris, 1900. Total eclipse of the Sun, May 28, 1900.
(*American Ephemeris Office.*) 8vo. Washington, 1900
—— : Astronomical papers prepared for the use of the American

Washington, Navy Department—*continued.*
Ephemeris and Nautical Almanac. Vol. 7, part 3–4; Vol. 8, part 2.
(*The Bureau.*) 4to. Washington, 1898–99
Vol. 7, part 3. S. Newcomb. Tables of the heliocentric motion of *Uranus.*
„ „ 4. S. Newcomb. Tables of the heliocentric motion of *Neptune.*
Vol. 8, „ 2. Catalogue of fundamental stars for 1875 and 1900, reduced to an absolute system.

Washington, National Academy of Sciences:
Memoirs. Vol. 8, third and fourth memoirs.
(*Academy.*) 4to. Washington, 1899
3. W. S. Eichelberger. General perturbations of *Minerva* (93).

Washington, Smithsonian Institution:
Smithsonian Miscellaneous Collections. Vol. 40, No. 1171; vol. 41, No. 1173.
(*Institution.*) 8vo. Washington, 1899

Washington, U. S. Bureau of Education:
*Report of the Commission of Education for 1897–98. Chap. 18: Teaching of Astronomy.
(*Prof. Holden.*) 8vo. Washington, 1899

Washington, United States Naval Observatory:
—— : Report of the Superintendent . . . for the year ending June 30, 1899.
(*Observatory.*) 8vo. Washington, 1899
—— : Report of the Board of Visitors, 1899.
(*Observatory.*) 8vo. Washington, 1899

Waterhouse (James):
*Teachings of Daguerreotype.
(*Author.*) 8vo. London, 1899

Weinek (Ladislaus):
—— : Photographischer Mond-Atlas, vornehmlich auf Grund von focalen Negativen der Lick-Sternwarte, im Massstabe eines Monddurchmessers von 10 Fuss. Heft 7–9.
(*Prof. Weinek.*) fol. Prag, 1899–1900
—— : * Über die beim Prager photographischen Mond-Atlas angewandte Vergrösserungsmethode.
(*Prof. Weinek.*) 8vo. Wien, 1899
—— : * Astronomie an der deutschen Carl-Ferdinands-Universität in Prag während der letzten fünfzig Jahre.
(*Prof. Weinek.*) 8vo. Prag, 1899

Whittaker (Edmund Taylor):
* Report on the progress of the solution of the problem of three bodies.
(*Author.*) 8vo. London, 1899

Wilson (William E.):
Astronomical and physical researches made at Mr. Wilson's Observatory, Daramona, Westmeath.
(*Author.*) 4to. London, 1900

Wislicenus (Walter F.):
Astronomischer Jahresbericht; mit Unterstützung der Astronomischen Gesellschaft herausgegeben von W. F. W. . . . Band 1, enthaltend die Literatur des Jahres 1899.
(*Editor.*) 8vo. Berlin, 1900

Yale University Observatory:
Report for the Year 1898–99.
(*Observatory.*) 8vo. New Haven, 1899

Year Book of the Scientific and Learned Societies of Great Britain and Ireland, 1899.
(*Turnor and Horrox Fund.*) 8vo. London, 1900

Yerkes Observatory of the University of Chicago:
—— : Bulletin, No. 7–12.
(*Observatory.*) 8vo. Chicago, 1899
—— : Publications. Vol. 1.
(*Observatory.*) 4to. Chicago, 1900
S. W. Burnham. A general catalogue of double stars discovered from 1871 to 1899.
—— : Second Annual Report of the Director . . . for the year ending June 30, 1899.
(*Observatory.*) 4to. Chicago, 1899

Zeitschrift für Instrumentenkunde: Organ für Mittheilungen aus dem gesammten Gebiete der wissenschaftlichen Technik. Jahrgang 19, Heft 5–Jahrg. 20, Heft 6.
(*Turnor and Horrox Fund.*) 4to. Berlin, 1899–1900

Zürich, Naturforschende Gesellschaft:
Vierteljahrsschrift, Jahrgang 44.
(*Society.*) 8vo. Zürich, 1899–1900

Zürich, Schweizerische meteorologische Centralanstalt:
Annalen, 1897. Jahrgang 34. 4to. Zürich, 1899

Zürich, Sternwarte des Eidg. Polytechnikums:
Publikationen . . . Band 2. Herausgegeben von A. Wolfer.
(*Editor.*) 4to. Zürich, 1899

PHOTOGRAPHS, &c., PRESENTED TO THE SOCIETY.

Barnard (E. E.)—Photograph of meteor trail (lantern slide).

Butler (C. P.)—Photograph of a bursting meteor (enlarged paper print and lantern slide).

Cambridge University—Jubilee Medal of Sir G. G. Stokes, 1899 (bronze).

Hodges (S.)—Oil painting of the moon.

Lick Observatory—Photographs of star clusters, nebulæ, and stellar spectra, and of the total solar eclipse 1898 January 22 (10 enlargements on glass, from photographs taken with the Crossley reflector, &c.)

Maskelyne (J. N.)—Kinematograph film of eclipse of the Sun, 1900 May 28.

Potsdam Observatory—Photograph of the great refractor.

Royal Meteorological Society—Jubilee Medal, 1900 (bronze).

Royal Observatory, Greenwich—Photograph of the Great Nebula in Orion (positive on glass).

Todd (D. P.)—Photograph of the transit of *Venus*, 1882 (enlarged paper print).

Wilson (W. E.)—Photograph of Nebula *H. V.* 14 *Cygni* (paper print and lantern slide).

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LX.

[*From Proceedings of the Royal Society, Vol. LXVII.*]

CONTENTS.

"Total Eclipse of the Sun, May 28, 1900. Preliminary Account of the Observations made by the Solar Physics Observatory Eclipse Expedition and the Officers and Men of H.M.S. 'Theseus,' at Santa Pola." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received June 22, 1900.—Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900.

The observing station selected for my party was determined upon from information supplied by the Hydrographer, Rear-Admiral Sir W. J. L. Wharton, R.N., K.C.B., F.R.S. Santa Pola appeared likely to meet the requirements of a man-of-war, and without such assistance as a man-of-war can render, the manipulation of long focus prismatic cameras in eclipse observations in a strange country is impracticable.

Santa Pola lies very near the central line of the eclipse, and [illegible] anchorage was available, protected from some wind

Before leaving England, I communicated with Professor Francisco Iñiguez é Iñiguez, Director of the Madrid Observatory, and Mr. Jasper Cumming, H.M. Vice-Consul at Alicante. These gentlemen, together with Don José Bonmati Mas, a large landed proprietor, and father of the Mayor of Santa Pola, very kindly made all the necessary preliminary arrangements with the local authorities, who had also been instructed by the Spanish Government, after representations had been made by the Foreign Office, at the request of the Royal Society.

As a result of the Royal Society's application to the Admiralty, H.M.S. "Theseus," commanded by Captain V. A. Tisdall, R.N., was told off to meet the expedition at Gibraltar, and convey the observers to Santa Pola.

The expedition consisted at first of Dr. W. J. S. Lockyer, from the Solar Physics Observatory, Mr. A. Fowler, the demonstrator in Astronomical Physics, from the Royal College of Science, and Mr. Howard Payn, who joined as a volunteer; I subsequently received orders to accompany and take charge of it.

Mr. Payn went on in advance overland to make preliminary arrangements and to lay out the camp on a plan which had been previously arranged, while the remaining observers left England on May 11, by the R.M.S. "Oruba," of the Orient line.

On arriving at Gibraltar, the party at once went on board H.M.S. "Theseus," and left for Santa Pola, which was reached just before noon the following day, May 17. I was glad to find that great interest had been shown in the expedition before our arrival on board, and that lectures on the work to be undertaken had already been given by the Chaplain, the Rev. G. Brooke-Robinson, M.A.

Assistants were at once forthcoming for working the prismatic cameras, and also for manipulating several cameras which I had brought out to be used by the ship's company in obtaining photographs of the corona.

Observing parties in charge of officers of the ship, to make observations along several lines, were at the same time organised.

On our arrival at Santa Pola, the following local officials came on board with Mr. Payn:—Sns. Francisco Bonmati Mas, Mayor of Santa Pola; Antoine Bonmati Mas, Vice-Mayor of Santa Pola; José Bonmati Mas, Municipal Councillor; José Salinas Perez, Municipal Councillor; Eladio Ponce de Leon, Secretary to the Mayor; Michel Sempere, Justice of the Peace; José Hernandez, Captain of the Port; Geronimo Agnati, Administrator of Customs; Eduard Fernandez, 1st Lieut. of Coast Guards; Tomas Bueno, Medical Officer.

They informed us that permission had been given for landing parties from the man-of-war, and special facilities granted for landing instruments and personal baggage without Custom's examination.

The erection of the instruments, huts, and tents was commenced on

the following morning, May 18, and by the evening of May 21 the principal instruments were reported in approximate adjustment. Drills were begun on May 22, and were carried on several times a day up to the day of the eclipse. In this work the eclipse clock, which I have described in previous eclipse reports, was used.

By permission of the Captain, three of the officers of the "Theseus," Lieuts. Andrews, Doughty, and Pattrick, R.N., occupied quarters on shore to superintend the work of the parties in the camp. On board, the Chaplain gave instructions in sketching coronas and recording stars, using for this purpose a lantern which had been placed at the disposal of the expedition by the Orient Steam Navigation Company.

The weather was very favourable for the work of the expedition, but at times the landing and embarking of parties from the ship was rendered difficult by strong sea breezes and the consequent surf.

Both day and night the instruments were carefully guarded by a detachment of "Guardias Civiles," told off for the purpose by the Spanish authorities.

The groups of observers were as follows:—

LIST OF ECLIPSE PARTIES.

Timekeepers.

Lieut. F. A. Andrews, R.N.	J. Wale, 2nd Yeoman Signals.
Mr. Boughey, Mid.	W. Webb, P.O. 1.
Mr. Lambert, Mid.	Bugler Sneller, O.S.

6-inch Prismatic Camera.

Dr. Lockyer.	C. Willmott, O.S.
S. Birley, E.R.A.	A. Humphries, O.S.
J. Green, A.B.	G. Hyatt, O.S.
C. Fishenden, O.S.	

20-foot Prismatic Camera.

Mr. Fowler.	A. Maskell, A.B.
W. F. Cox, Armr.	E. Davies, O.S.
A. Whitbourne, A.B.	H. Cristopher, O.S.
F. Burt, A.B.	W. Harrison, Sto. Mech.

4-inch Equatorial.

Sir Norman Lockyer, K.C.B.	C. C. Lambert, Mid.

3¾-inch Equatorial.

Lieut. H. M. Doughty, R.N.	A. G. N. Lane, Mid.

Long-focus Coronagraph.

Mr. Payn.	H. Eary, A.B.
T. McGowan, A.B.	W. Mann, O.S.
E. Woodland, A.B.	H. Brooks, O.S.

Graham Coronagraph.

Mr. W. J. S. Perkins, Asst. Engr., R.N. J. Knowles, Chief Stoker.
W. Walker, Lg. Stoker.

De La Rue Coronagraph.

Mr. H. W. Portch, Asst. Engr., R.N. H. Frost, Chief Stoker.
W. Waterfield, E.R.A.

Dallmeyer Coronagraph.

Surgeon J. Martin, R.N. R. Quint, Chief Stoker.
E. Buckingham, E.R.A.

Discs.

Mr. J. B. Bateman, Mid. R.N. W. Fraser, Arm. Crew. R. S. Bradbrooke, A.B.	Mr. J. A. Daniels, Torp. Gunner, R. G. Fair, Armourer. E. Gordon, S. Carp.
H. W. Richardson, P.O. 2. E. Voyle, Lg. Shipwt. T. Orange, Boy, 1 c.	W. Tucker, A.B. W. Brewer, A.B. B. Salmon, Boy, 1 c.
A. Mason, A.B. A. Steven, A.B. C. Paul, Boy, 1 c.	A. May, A.B. H. Bailey, A.B. J. Entwistle, S. Std. Boy.

Sketches of Corona without Discs (on shore).

W. Butt, M.A.A. H. Meacher, Pte. R.M.L.I.
G. Guilliame, A.B. H. Schmidtœl, O.S.

Sketches of Corona without Discs (on board).

W. Baxter, A.B. J. Wheeler, Pte. R.M.L.I.
W. Butts, Pte. R.M.L.I. E. Willis, S.B. Attendant.
C. Jacob, Pte. R.M.L.I.

Observations on Stars (on shore).

Mr. Bennett, Clerk. H. Angus, O.S.
W. Riches, L. Seaman. W. Kinvett, Pte. R.M.L.I.
A. Pontifex, A.B. W. Oliver, Pte. R.M.L.I.
W. Bosworth, A.B.

Observations on Stars (on board).

Rev. G. B. Robinson, M.A. E. Hammond, Sto.
H. Croxon, S. Corpl. G. Andrews, Sto.
A. Phillips, Leading Shipwt. G. Nightingale, Sto.
R. Vigus, Corpl. R.M.L.I. S. Wilson, Sto.
E. Price, Pte. R.M.L.I. E. Savage, Pte. R.M.L.I.

Observations of Shadow Bands (on shore).

Commander Hon. R. F. Boyle, R.N. Mr. J. G. Walsh, Mid. R.N.
Mr. T. Slator, Naval Instructor, R.N. Mr. F. C. Skinner, Mid. R.N.

Meteorological Observations (on shore).

Lieut. Pattrick, R.N. Mr. G. S. Hallowes, Mid. R.N.

Meteorological Observations (on board).

G. Donnelly, Yeom. Sig.
E. Gant, Lg. Sig.
A. Enstidge, Sig.
W. Hearne, Sig.
J. Beach, Sig.

Landscape Colours (on shore).

Capt. F. V. Whitmarsh, R.M.L.I.
Ship's Steward D. Green.
Lance-Corpl. Wade, R.M.L.I.
W. Birkett, Writer.

Landscape Colours (on board).

Fleet Paymaster A. W. Askham, R.N.
Lieut. W. J. Frazer, R.N.

Shadow Phenomena (on shore).

Mr. C. Prynn, Carpr. R.N.

Shadow Phenomena (on board).

Lieut. H. R. Shipster, R.N.

Photographers.

J. Knight, S.B. Steward.
B. Bulbrook, A.B.

Aide-de-Camp to Sir Norman Lockyer, K.C.B., F.R.S.

Mr. C. C. Lambert, Mid. R.N.

Time Arrangements.

According to the Admiralty chart, the latitude and longitude of the place of observation are 38° 11′ 20″ N. and 0° 33·66′ W. respectively. For this point, the times and position angles of contact derived from the formulæ given in the 'Nautical Almanac Circular,' No. 17, were as follows:—

Beginning of totality, May, 28 d. 4 h. 12 m., 51·7 s.
End „ „ 4 h. 14 m., 10·5 s.
Duration of totality .... 1 m., 18·8 s.
Position angle of first contact, 87° 3·5′ from N. towards W.
„ „ last „ 93° 47·3′ „ „ E.

The experience of the Indian eclipse of 1898 suggested that the duration of totality was too long, and for the practical working during the eclipse the adopted time was 75 seconds, so that there would be no chance of spoiling the coronagraph plates by exposing them after totality. The face of the eclipse clock was graduated accordingly.

The arrangements for securing signals at definite intervals before totality was identical with that employed in Lapland and India. An image of the sun projected by the finder of the 6-inch two-prism prismatic camera was viewed on an adjustable screen, marked in such a way that it was easy to see when the cusps subtended angles of 90°

nd 55°, which occurred respectively at 16 secs. and 5 secs. before otality. The signals "Go" at the commencement of totality, and Over" at the end, were given by myself, from observations made ith the 4-inch Cooke telescope.

Results.

Some of the photographs have not yet been developed, and the eports have not yet been received from the ship's parties, so that nly a very brief reference to the work accomplished is possible.

The Prismatic Cameras.

The discussion of the series of photographs taken with the prismatic ameras employed in the last three eclipses indicated that continued ork with this form of spectroscope should be undertaken, (1) with he view of obtaining data strictly comparable with the previous hotographs, and (2) that an effort should be made to extend the nquiry into comparative lengths of the various arcs. For the first urpose it seemed desirable to repeat the Indian work with the 6-inch amera having two prisms, while for the second an instrument of longer focus was necessary.

Representations as to the importance of the latter instrument were made to the Royal Society, and ultimately the purchase of a Taylor triple lens of 6 inches aperture and 20 feet focal length was authorised. This was received so shortly before the expedition left England, that it was only possible to make a rough trial of the instrument before it was set up at Santa Pola. Both prismatic cameras were worked in conjunction with siderostats, calculations having shown that the position angles of contact were favourably situated after reflection.

Dr. Lockyer took charge of the two-prism instrument, and Mr. Fowler of that having a long focus, and in each case the programme of exposures was successfully performed.

The photographs which have been developed indicate the same succession of phenomena recorded in the three previous eclipses, but the recent eclipse was specially advantageous, for the reason that the chromospheric arcs at the instant of contact were of greater length.

A very complete record of the spectrum of the chromosphere at various depths has been secured with both instruments, and it seems probable that new information as to the distribution of the various vapours will be furnished by the photographs taken with the long-focus instrument.

The spectrum of the corona shows the green ring at 5303·7, the blue ring at 4231, and the violet ring at 3987·0: others may possibly appear on closer examination. All the rings are of totally different character from the chromospheric arcs, and have their greatest bright-

ness in regions other than those where the chromospheric arcs are brightest. As before, 3987·0 is much more uniform in brightness throughout the extent of the ring than the others; 5303·7 is especially strong in one or two regions; but on the whole is probably weaker than in 1898.

The photographs show that the scale of the spectra is by no means too large for work with short exposures with a lens of 6 inches aperture. The spectra are 7·5 inches long from D_3 to K, and the diameter of the rings is 2·5 inches; photographs taken with an exposure estimated at $\frac{1}{4}$ of a second are fully exposed.

The Differences between the Coronas observed at the Periods of Sun-spot Maxima and Minima.

My attention was called especially to these differences, because I saw the minimum eclipse of 1878, while the phenomena of that of 1871 (maximum) were still quite fresh in my mind. My then published statements have been amply confirmed during the eclipses which have happened since 1878, but certainly the strongest confirmation has been obtained during the present one, which took place two more spot periods after 1878.

1. *Form.*

With regard to form, at the instant of totality I saw the 1878 corona over again, the wind vane appearance being as then most striking.

2. *The Spectrum.*

In connection with the eclipse of 1878 (minimum), I pointed out that, whereas in 1871 (maximum) the spectrum of the corona viewed by small dispersion was remarkable for the brightness of the lines; in 1878 they were practically absent, and the continuous spectrum was remarkably brilliant.

I determined therefore to make a similar observation in this year of maximum, and, as in 1878, used a grating first order spectrum placed near the eye. The result was identical with that recorded in 1878. I saw no obvious rings or arcs, but chiefly a bright continuous spectrum.

3. *The Minute Structure of the Inner Corona.*

Lieut. Doughty, R.N., and myself made observations on the minute structure of the corona, in order to see if any small details could be observed, and whether they were the same as those I saw so well and recorded during the eclipse of 1871, at a period of sun-spot maximum. This question was specially taken up this year, as exactly two sun-spot periods have elapsed since 1878.

In 1871 I used a 6-inch object glass, and distinctly observed marked delicate thread-like filaments, reminding one of the structure of the prominences, with mottling and nebulous indications here and there; some of these distinct markings were obvious enough to be seen till some minutes after totality.*

This year, with a perfect 4-inch Taylor lens and a high power, not the slightest appearance of this structure was to be traced; the corona ome 2′ or 3′ above the chromosphere was absolutely without any etailed markings whatever.

Lieut. Doughty duplicated and confirmed these observations with a ¾ Cooke. Here, then, is established another well-marked difference between maximum and minimum coronas.

The Coronagraphs.

Four coronagraphs were employed of various apertures and focal ngths. One, of 4 inches aperture and 16 feet focal length, was in harge of Mr. Howard Payn, while the others were controlled by fficers of the ship.

The results obtained are very satisfactory, those taken with the long-focus instrument being especially good. In this case the image is 1¾ inches in diameter, and the definition is perfect. The photograph taken with an exposure of 5 seconds shows a great wealth of detail in the inner corona and prominences; the fine definition appears to be due to the fact that a Taylor photo-visual lens was employed, bringing the rays of various refrangibilities to the same focus. A long exposure photograph, with the same instrument, is remarkable for the perfect hardness of the moon's edge, notwithstanding the motion during totality.

The three photographs secured by Asst. Engineer Portch, R.N., with the De la Rue lens of 4⅝ inches aperture, give also sharp images with much fine detail.

Sandell triple-coated plates were used with this instrument.

With the 6-inch Dallmeyer lens, two photographs on Sandell plates were obtained by Dr. Martin, R.N., one being exposed for about half a second, and another for 50 seconds.

The longer exposure records the extensions to a greater distance from the dark moon than any of the other photographs obtained, with the exception of the one secured with the small-grating camera.

This last-mentioned instrument consisted of a Zeiss anastigmatic lens of 9 inches focal length, with a small Thorp grating mounted in front of it. The exposure of the plate was 40 seconds during totality; the longest streamer in the N.E. quadrant extends to a distance of 4½ lunar diameters.

* 'Solar Physics,' p. 372.

Discs.

Six discs for cutting out the bright light of the inner corona were erected, with the view of enabling the observers to detect the long extensions if there should be any. They were very carefully set up by Lieuts. Doughty and Andrews, R.N., and were provided with eye-pieces having all necessary adjustments. Mr. Daniels, torpedo gunner, then took charge of the party, and numerous rehearsals were given. In the trials remarkable skill in recording delicate details was displayed.

During the eclipse, the actual observer was blindfolded for five minutes before totality.

No extensions of the nature observed by Professor Newcomb in 1878 were recorded.

Observations on the Stars Visible during Totality.

A large party for the observation of stars visible during totality was trained and organised by the Chaplain, Rev. G. Brooke-Robinson R.N., who was provided with a set of star charts for purposes of instruction prior to the eclipse, and another set, prepared by Dr. Lockyer, for making records during the eclipse.

Venus became visible at a very early stage of the eclipse, and during totality Mercury was a very conspicuous object near the extremity of one of the streamers. α Tauri, α and γ Orionis were also recorded. No comet or unknown body was noted.

Shadow Bands.

The Naval Instructor on H.M.S. "Theseus," Mr. T. Slator, B.A., undertook this branch of the eclipse work, and during the eclipse worked in conjunction with the Commander, the Hon. R. F. Boyle. Very complete arrangements were made for securing the orientation of the bands (1) on a horizontal plane; (2) on a plane in the meridian; (3) on a plane in the prime vertical. The bands appear to have been very ill-defined, but the necessary observations were secured in planes 1 and 2.

Meteorological Observations.

A regular series of observations of temperature and pressure was established three days before the eclipse, and continued until two days after; Lieut. Pattrick, R.N., taking charge of this branch of the work. During the eclipse the temperature fell 5° C., and the barometer also fell slightly.

The thanks of the expedition are due especially to those named in

the foregoing account, not only for assistance rendered, but also their great kindness to us. I have already, in a letter, expressed the Royal Society my deep sense of the obligation they have laid under.

As in the case of the "Volage" and "Melpomene," the officers men of the "Theseus" not only assisted us with certain instrume but organised crews for others, and many lines of work which it impossible for the observers sent out from England to attempt. T skill, resourcefulness, and steadiness were alike truly admirable.

Thanks are also due to the Managers of the Orient Steam Na tion Company, who conveyed the instruments to and from Gibr freight free.

I may add, the Civil Governor of the Province of Alicante, S don Hipoldo Caras y Gomez de Andino, visited the camp to as himself that all the assistance the Spanish authorities could give been rendered.

"Total Solar Eclipse of 1900 (May 28). Preliminary Report the Observations made at Bouzareah (in the Grounds the Algiers Observatory)." By Professor H. H. TURI M.A., F.R.S., and H. F. NEWALL, M.A., Sec. R.A.S. Recei June 28,—Read at Joint Meeting of the Royal and R Astronomical Societies, June 28, 1900.

The Report is presented in three parts.

PART I. ORIGIN OF THE EXPEDITION AND GENERAL PREPARATIONS BY TWO OBSERVERS JOINTLY (§§ 1—10).

PART II. SEPARATE REPORT BY PROFESSOR TURNER.

§§ 11—12. The Cameras and Cœlostat.
§ 13. The Polariscopes.
§§ 14—16. Adjustments.
§§ 17—19. Programme of Observations.
§§ 20. The Standard Squares.
§ 21. Use of Green Screen.
§ 22. Integral Photometer.
§ 23. Development.

PART III. SEPARATE REPORT BY MR. NEWALL.

§ 24. The Four-prism Spectroscope with Slit.
§ 25. The Photographic Camera with large Objective Grating.
§ 26. The Polariscopic Camera (Savart Plates and Nicol Prism).
§ 27. Atmospheric Polarisation.
§ 28. General Observations.

Part I.

1. *Origin of the Expedition.*—This expedition was one of those rganised by the Joint Permanent Eclipse Committee of the Royal ociety and Royal Astronomical Society, funds being provided from a rant made by the Government Grant Committee.

The expedition was most cordially and hospitably assisted by M. Trépied, the Director of the Algiers Observatory, and the observers re indebted to him in numberless ways for his kindness. He assigned ood positions for the instruments in the Observatory grounds, and had rick piers built beforehand according to plans supplied to him by the bservers. He made the arrangements for conveying the instruments o and from Algiers; and put at the disposal of the observers a pacious dark room (which we believe he had specially arranged for he purpose) and the services of a carpenter.

2. *Mr. Wesley's Observations.*—It may be here mentioned, although it loes not come strictly within the scope of this report, that M. Trépied llowed Mr. W. H. Wesley, the Assistant Secretary of the Royal Astronomical Society, who has had great experience in drawing the orona from photographs, to use the equatorial coudé of the Algiers Observatory during this eclipse; and Mr. Wesley was thus enabled to nake his first eye observations on the corona itself under most favour-ble conditions. He joined the present expedition, but as he was the missary of the Royal Astronomical Society and not of the Joint Committee, the report of his observations is not included here. That M. Trépied should have placed the finest instrument in the Observatory t the disposal of a foreigner is a striking instance of his scientific iberality; and the observers call attention to it because it will indicate nore clearly than any enumeration of details the kind of assistance for vhich they have to thank him.

3. *Personnel.*—The following persons took part in the expedition:—

H. H. Turner, M.A., F.R.S., Savilian Professor of Astronomy at Oxford.

H. F. Newall, M.A., Sec. R.A.S., Observatory, University of Cambridge.

4. *Itinerary.*—The observers left Charing Cross at 11 A.M. on Satur-lay, May 12. They spent one day in Marseilles, and arrived at Algiers n Tuesday, May 15, proceeding in the evening of the same day to the ittle village of Bouzareah, which they made their headquarters, about a mile from the Algiers Observatory. The instruments had been sent ound by sea (through the Papayanni Steamship Company), and should have arrived on May 10, but for some reason they did not arrive until May 17, and were delivered at the Observatory on the evening of May 18. Three whole working days of the eleven which had been

counted on were thus lost, and in order to carry out the program an undesirably great press of work was necessary. The day of eclipse was fine, and many good photographs were obtained. The development of these and the packing up of the instruments for occupied the observers till Friday, June 1. They left Algiers on Saturday, June 2, and arrived in London on Monday, June 4. But they would record the opinion that the time spent on the expedition was too short. The work was got through, but with practically no margin for contingencies, and would have been done better with another week at least.

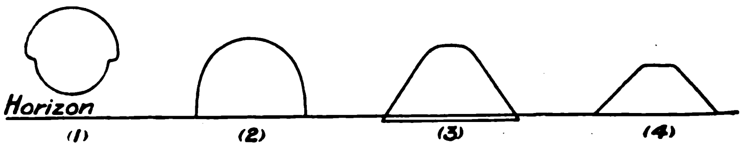
5. *Position of Station.*—The station was on the west side of the equatorial coudé, and about 50 yards S.E. of the transit-circle, the position of which is

Longitude......... $0^h 12^m 8^s{\cdot}7$ E. of Greenwich.
Latitude .... $36^\circ\ 48'\ 0''{\cdot}5$ N.
Height above mean sea level, 1123 feet.

This spot was some distance from the central line, and 4 or 5 seconds of the 70 seconds of totality available were thus lost; but the loss was more than counterbalanced by the many advantages of being at a fixed observatory.

6. *Meteorological Conditions.*—As regular meteorological observations were made at the Observatory, none were made by us. The day of the eclipse was the finest of our stay, and fine days preceded and followed it. On May 26, 27, and 28 the sun was seen to set in the sea, and the "green ray" was looked for and seen by several observers.

The disc, when near the horizon on May 28, assumed remarkable shapes, of which the following four types were noticed by several observers:—



There was at times considerable wind, as M. Trépied had warned us, but the day of the eclipse was calm.

7. *Instruments, &c.*—(See separate reports of observers.)

8. *Huts.*—Willesden canvas over wooden framework was used, and found very satisfactory, as before.

Mr. Newall's hut was designed for his particular instruments, and the openings were obtained by leaving the canvas loose in the form of flaps, which were tied in the proper positions, either open or closed.

Professor Turner's hut was designed for general requirements, and has now been used, not only in this expedition, but as a transit hut in the determination of the longitude of Killorglin by the staff of the Royal Observatory, Greenwich, in 1898. As it appears to satisfy the conditions, the following notes of its structure may be useful to others:—

It is a skeleton wooden framework filled in by a series of panels, any one of which is removable without disturbing any other by simply taking out two screws. The panels forming the sides drop into a groove running round the base, and two screws are sufficient to hold them at the top. For the roof panels it is the upper edges which push into grooves along the central ridge, and the two fixing screws are near the eaves.

The panels themselves are rectangular wooden frames with canvas stretched over them. For transport, the sides are unscrewed, and then the canvas is rolled round the ends like a window blind.

The screws which fix the panels in position in the hut terminate in rings instead of the ordinary screw heads, so that they can be screwed up or unscrewed with the fingers instead of with a screw-driver, which may not be handy at the moment.

It may be remarked that both the huts were securely fastened down on this particular occasion, as the wind sometimes blew a gale.

9. *Assistance.*—The observers were assisted in the exposures as follows:—

Mr. H. Wyles, of the Leeds Astronomical Society, counted seconds aloud from a metronome.

Mr. J. Potter, of Leeds, carried from Mr. Newall's hut the information of the setting of the Savart prism (which Mr. Newall was to observe during totality) to Major K. O. Foster, who set the corresponding instrument in Professor Turner's hut (see separate report of Mr. Newall). It was originally intended to shout this information, but as it was found in the rehearsals that there was occasionally difficulty in hearing, Mr. Potter undertook this conveyance as a safeguard. As the event proved, his assistance was all important, for at the actual eclipse there was so much noise from other observers in the neighbourhood that the shout was not heard at all.

Major K. O. Foster, F.R.A.S., set Mr. Newall's savart between the second and third exposures, and at the same time changed the slit of Professor Turner's polariscope. He also uncovered the plates for long exposure soon after the beginning of totality and covered them before the end.

Mr. F. L. Lucas, of Berkhamsted, made the exposures for Professor Turner at the objective.

Master Eric Henn handed the plates.

Mr. F. L. Crawford, of the Indian Civil Service (who had seen the

1898 eclipse at Berar), received the plates, recorded the times, and also exposed for 10 seconds the integral photometer.

Mr. Lovett Henn, of Algiers, made the exposures with the grating for Mr. Newall.

Mrs. Newall made observations of the atmospheric polarisation during totality.

At 15 seconds before totality, as shown by the diminishing crescent of the sun, Professor Turner called "Stand by"; at totality, "Start": when Mr. Wyles counted from the metronome steadily up to 80. Totality lasted 64 or 65 seconds, and the extra 15 seconds was required by Mr. Newall for exposures at the second "flash." The signals were given with approximate correctness, though, by an oversight, no one timed the interval between the "Stand by" and the "Start."

The operations were rehearsed several times on the day before the eclipse, and once or twice in dumb show on the actual day. It was not found possible to arrange for rehearsals earlier; but, with the exception of the omission just noticed, everything went off at the time without a hitch.

10. *The Day of the Eclipse.*—Perfectly clear all day—no anxiety. The contacts were not observed by us with special care as we had much else to do, and observations were being made by the staff of the Observatory. M. Sy kindly supplied the following predictions and observations:—

	Predictions.	Observations.
1st contact......	3^h 17^m 21^s	3^h 17^m 18^s
2nd ,, ...	4 29 25	4 29 27
3rd ,, ...	4 30 32	4 30 32
4th ,, ...	5 34 31	5 34 25

Local mean time (12^m $8^s \cdot 7$ in advance of G.M.T.).

Lamps were not needed during totality.

Owing to an accident (a signal being lost through noise made by others) the shadow was not observed. Major Kingsley Foster noticed the "shadow bands" on the white surface of the "double tube" near which he was stationed.

PART II.—SEPARATE REPORT BY PROFESSOR TURNER.

Instrumental Equipment.

11. *The Cameras.*—The double camera used at Fundium in 1893 (by Sergeant Kearney), and at Sahdol in 1898, was modified on the present occasion. One of the 7 × 7-inch tubes contained, as before, the photoheliograph objective No. 2 of 4-inch aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of $7\frac{1}{2}$ inches focus placed

3 inches within the focus, giving an image of the sun 1⅜ inches in diameter; but the "Abney" lens was no longer used in the other tube. It had been decided by the Joint Permanent Committee to discontinue the separate use of the two Abney lenses, and to recombine them into the original doublet, which Mr. Davidson was to use in the expedition organised by the Astronomer Royal. Hence the other half of the double tube camera was set free, and it was utilised to good effect by arranging *two* polariscopic cameras to give images on the same plate, a diagonal partition dividing the square tube into two. One instrument was arranged by Mr. Newall, and is described by him. The other was similar to the apparatus used by me in India in 1898, but with improvements in detail as described below. The double camera is furnished with six plate holders, each taking two plates of 160 × 160 mm. (as in use for the Astrographic Chart), both plates being exposed by a quarter turn of one shutter.

Alongside the double tube two other cameras were arranged for single exposures during the greater part of totality. One was a portrait lens of 5¼ inches aperture and 30 inches focus, stopped down to *f*/8; the other was a small polariscopic camera, described below.

12. *The Cœlostat.*—All these cameras were pointed downwards at an angle of 18° with the horizon, in azimuth 42° west of south, to the 16-inch cœlostat used in India in 1898. The mirror of this instrument was made by Dr. Common. It was silvered and sent out to Algiers by the Improved Electric Glow Lamp Company, and had a very fine surface. The mounting and clock of the instrument were made by Mr. J. Hammersley, from designs by Dr. Common. A steadier mounting is desirable on future occasions, though the present arrangement works well when there is not much wind to cause vibration.

13. *The Polariscopes.*—The arrangement used in India was as follows:—

(A) Objective, 3½ inches aperture, 18 inches focus.
(B) Slit, of width 0·2 inch, in cardboard.
(C) Collimator, 1½ inches aperture, 6½ inches focus.
(D) Rhomb of spar, 1 inch aperture (clear).
(E) Camera, 2 inches aperture, 9 inches focus.

On the present occasion (E) was substituted for (A), which was of inconvenient width for the space at disposal. The primary image was thus reduced to half the size; but this had the advantage that a larger part of the image fell on the slit, the width of which remained the same as before, being governed by the focal length of the collimator and the angular separation of the images by the rhomb. The collimator (C) and the rhomb (D) remained unchanged, but the camera lens (E) was now a photographic objective of 1½ inches aperture and 28 inches focus, made specially by Messrs. Cooke and Sons, of York

The plate holder was of course that of the double tube, as above explained.

The slit (B) was arranged, as in 1898, in two portions, but was on this occasion made in brass.

The slit and rhomb were connected by a bar, and could be rotated sympathetically. They were set at such a position angle that the lines of the image parallel to the slit corresponded to vertical lines on the corona; but this setting was found after the eclipse to be not quite accurate. The setting was not changed during totality, but the slit was moved in the direction of its length, so as to give a different part of the field between the second and third exposures.

The small polariscope exposed separately resembles the objective prism spectroscope as opposed to the slit spectroscope. The reason for adopting the slit spectroscope form for the instrument above described is that the angular separation of images given by the large rhomb was not large, and if this rhomb had been simply placed in front of an objective, one image of the corona would have seriously overlapped the other. But a small rhomb (kindly lent me by Mr. Newall) gave a separation of 3½°, so that when the corona was viewed through this rhomb and an objective the two images polarised in perpendicular planes were clearly separated, though each was projected on the sky of the other. To cut out the sky backgrounds, a slit, of 1 inch aperture, was placed 15·7 inches in front of the rhomb.

Instrumental Adjustments.

14. *Adjustment of Cœlostat.*—The adjustment of the polar axis was made as described in the Report on the Japan Expedition,* by means of the attached declination theodolite. This was a new one, by Messrs. Troughton and Simms, of rather smaller size than the others, with a 3-inch circle reading to 1′ only. When the three eclipse cœlostats were constructed, theodolites were only supplied with two of them; and as in 1896 and 1898 there were two cœlostats at the same station, one theodolite sufficed for adjusting the two. But this arrangement was only provisional, and on the present occasion, when all three cœlostats went to different stations, it became necessary to provide the third theodolite. From previous experience I judged that the smaller size would be sufficient for the purpose.

The following observations will sufficiently indicate the state of adjustment, those with the level being made on the meridian and compared with the known latitude, so as to give the same sign to the errors as the sun observations :—

* ...es, R.A.S.,' vol. 57, p. 102.

Date.	Sun's H.A.	Obs. decl.	Tab. decl.	O—C.
May 22......	−3·0	+20° 17′	+20° 20′	−3′
		Observation with level		−1
May 29......	−1·0	+21° 36′	+21° 35′	+1′
		Observation with level		−1′

On the present occasion the cœlostat was not blocked with wood as in India; but it was found liable to slight vibration, and a firmer support should be provided for future eclipses.

15. *Tilt of Mirror.*—The time available for preparation was so fully occupied that no special observations for tilt of the mirror were made, but in India there was found to be no appreciable tilt.

16. *Focussing of Telescopes.*—The method adopted for the photoheliograph objective and magnifier was that described in the Report on the Japan Expedition.* The position found was very close to that found in previous expeditions. The object glass was unscrewed a quarter turn, *i.e.*, 0·02 inch, differing 0·02 inch from the position in 1898, as indicated by a wooden gauge.

The polariscopes were focussed on a distant view (a clear view of 7 or 8 miles across the bay was on this occasion available) through blue glass.

The portrait lens was first focussed by blue glass, and then three photographs of the distant view were obtained, which gave the focus sharply.

A focussing eye-piece made in blue glass, kindly lent by M. Trépied, was found very useful. I do not know whether this simple and convenient apparatus is well known; it is made by Hermagis, of Paris.

17. *Programme of Observations with Double Tube.*—The six slides of the double tube camera were filled with "Rocket" plates; four of them only were to be used during totality, the others being available for supplementary short exposures if time should allow. As it turned out, there was no time for more than the four, and the others were exposed just after totality. The actual exposures were as below :—

No. of slide.	Exposure in seconds.	Time in beats from commencement of totality.	Time in seconds.
1	1	6—7	5—6
2	5	13—18	12—17
(Setting of Savart and slit between these.)			
3	19	31—51	29—48
4	5	55—60	52—57
End of totality		66	62
5	1	68—69	64—65
6	1	75—76	71—72

* 'Monthly Notices, R.A.S.,' vol. 57, p. 105.

The times after totality are diminished to get true seconds. The numbers in the third column are beats of a metronome, which, though adjusted beforehand, changed its rate, perhaps owing to the fall of temperature. Just after totality it was found to beat sixty-three times to the minute. Further, the word "One" was called on an actual beat which came about 0·5 second after the word "Start" (signifying the commencement of totality) had been called. This signal was given by me from a direct observation of the disappearance of the crescent, and agreed well with the observations of others. The signal for 15 seconds before totality was given to Mr. Newall by watching the length of the disappearing crescent on the focussing glass of the camera, and was approximately correct, though by an oversight no one observed the interval; but after giving this signal, as I found the direct light of the crescent did not hurt the eyes, I watched that in preference to the image on the glass. I saw the complete ring of the moon's disc quite 10 seconds before totality, and from that moment the corona seemed to grow out from the limb in a most beautiful manner.

18. *Programme for the Polariscopes.*—The two polariscopes mounted in the double tube had of course exactly the same exposures as above.

Between exposures of slides 2 and 3 the Nicol prism and Savart plate of Mr. Newall's polariscopic apparatus were rotated by Major K. O. Foster to the reading indicated by Mr. Newall's eye observations; and the slit of my apparatus was also moved by Major Foster to the second position, so that the second pair of photographs gave a different part of the corona from the first.

The smaller polariscope was exposed from 5 to 60 seconds, counting from the beginning of totality.

19. *Programme for the Portrait Lens.*—A Sandell triple-coated plate was exposed in this instrument. The exposure was made by Major Foster from 5 to 60 seconds, counting from the beginning of totality.

20. *The Standard Squares.*—On the six plates in slides, 1, 2, and 3, Sir W. Abney's "standard squares" were impressed for photometric observations of the corona. The exposures were to a standard candle at 5 feet from the plate, which is approximately twice as bright as the full moon. Assuming the brightest part of the corona to be as bright as the average surface of the full moon, the exposures to be given to the candle were calculated as follows:—

An image of the moon in the Dallmeyer lens of 4 inches aperture would be $1\frac{1}{2}$ inches in diameter. The illumination of the object glass is thus concentrated—

$$(4/1\tfrac{1}{2})^2 \text{ times} = 7 \text{ times}.$$

Hence the brightest part of the corona will affect the plate about seven times as much as direct moonlight, or three and a half times as much as a candle at 5 feet.

Hence to compare with a 1 second exposure to the corona through the lens, we should expose the plate to the candle for $3\frac{1}{2}$ seconds. Since the faintest of the standard squares obstructs some of the light, and since it is advisable to have an exposure on the plate from the standard light rather denser than the densest part of the image, the plates in slide No. 1 (to be exposed 1 second to the corona) were exposed for 6 seconds to the candle.

Those in No. 2 (to be exposed 5 seconds to the corona) were exposed for 40 seconds to the candle, and those in No. 3 (20 seconds to corona) for $2\frac{1}{2}$ minutes. These exposures are even longer, relatively, than No. 1; but on previous occasions the squares had not been dense enough, and it was considered advisable to make sure of going beyond the point required.

21. *Use of Green Screen.*—In slide No. 4 a coloured glass screen, kindly provided by Mr. Shackleton, was placed in front of the plate, with a view of obtaining information on the distribution of coronium in the corona by comparing a photograph taken in green light with the others. But owing to the following circumstance this particular experiment was not a success. The plate should of course have been one sensitive to green light, and some Cadett "spectrum" plates were taken out to Algiers for the purpose. They were whole plates and required cutting down to fit the slide. In the stress of other work the experiment was forgotten until an hour before totality. There was still plenty of time to fill the slide, and I went to the dark room to do so. But the circumstances were scarcely favourable for manipulating the diamond in the dark, as these plates require. The first plate broke and cut my finger, not seriously, but enough to hamper me, so that I had no better success in cutting another plate. Indeed, after one or two attempts I had to give it up. It seemed just worth while putting in a "Rocket" plate behind the green screen, but there was very little on the plate when developed; and the experiment was on this occasion of little or no value. I am sorry to have been unable to do justice to Mr. Shackleton's kindness in providing the screens, and hope that on another occasion I may make better use of them.

22. *An Integral Photometer.*—To obtain an estimate of the total light given by the corona, an Ilford "Empress" plate was exposed to its light for 10 seconds, in a small camera from which the lens had been removed, so that the corona shone directly on the plate, but side light was excluded. On the same plate standard squares were impressed by exposing it to the candle at 5 feet, as in § 8. The exposure given to the candle was, by an oversight, not recorded, but was either 10 or 20 seconds. The oversight was discovered before the eclipse, and another plate from the same batch was exposed to the candle and squares for 5, 10, and 20 seconds, and developed in the same dish. The effect of the corona was, however, considerably greater than that

C 2

It was intended to attempt—

(i) To secure photographs o
limb at the beginning and
the beginning, six at the e
(ii) To photograph the spec
regions of the corona.

It had been decided not to at
rotation of the corona, for the durat
to give satisfactory images of the li
at such distances from the limb a
certainty that the observations woul
ances known to exist near the chrom

The instrument arranged for the p
prism spectroscope with a single sli
India, at Pulgaon in 1898.* The o
(i) only one slit was used instead of
which had been found to give imperf
of homogeneity in the glass had been
prism box and train of prisms ha
Observatory for a star spectrograph, a
eclipse, after the completion of certai

The train of prisms is of such di
transmit a 2-inch beam of light
of 180° for H

object glass, by means of which an image of the sun can be thrown upon the slit.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown upon the slit does not rotate relatively to the slit. Furthermore, the mirror is mounted in such a manner that the axis about which it can be tilted—namely, the declination axis—can be oriented relatively to the collimator tube, so that any diameter of the sun may be set parallel to the slit.

A special plate holder was designed for use in Algiers in order to facilitate the rapid change of plates. It was charged with twelve plates, fixed film outwards on the outside of a cylinder (2 inches in diameter), whose axis was set parallel to the focal plane of the camera and in the plane of dispersion, free to turn inside a slightly larger covering cylindrical case. The arrangement was turned by hand, and worked admirably well. It is, however, only suitable for narrow spectrum plates, and might be used with very small alteration for a film on celluloid, such as is used in hand cameras of the Kodak type.

The linear dispersion in the photographed spectrum is about 14 tenth-metres per millimetre at H_γ. The width of the slit was adjusted to 0·03 mm. by a diffractional method.

The scale of the photograph is such that one degree on the sky corresponds to about 9 mm. on the plate.

The effective aperture of the combination regarded as an instrument for producing monochromatic images of a slit-shaped region of the corona is $f/10$.

The adjustment of the axis of the instrument to parallelism with the earth's axis was accomplished in the same way as in India by means of a theodolite with declination circle and level, which was attached to a part of the frame of the spectroscope specially prepared for it.

Programme of exposures, &c.:—

I. *Spectrum of the Sun's Limb at the Beginning of Totality.*—Five exposures were made in 7 seconds, beginning 3 seconds before Professor Turner's signal "Start" was called, and ending as Mr. Wyles called the "fifth" beat of the metronome.

Result.—The developed photographs show that the first plate was exposed at exactly the right moment to catch the spectrum of the "flash." It is filled with bright lines, and shows the part of the spectrum between H_ζ (3900) and H_β (4861). The best part of the spectrum is that between wave-lengths 4100 and 4650.

All the other four plates show bright lines, but the fall in the number of them is very abrupt between the first and the second plates.

II. *Spectrum of the Corona.*—Six seconds after Professor Turner's signal "Start" a plate was exposed for the spectrum of the corona, and

Fraunhofer lines have been
import when considered in
polarisation of the light emit

In one of the spectra the
H_γ, H_δ, H_ϵ, and H_ζ. In the
ing only very close to the lin
a quarter of a minute of arc.
barely perceptible in the other.
intensely strong and broadened,
lines very much shifted towards
other, the H and K lines are weak
important to note that the shift
direction that one would anticipa
broadening and of the shift. Wh
of the hydrogen, helium, and calci
of the two regions of the corona wl
is probably due to a prominence, t
cile with the signs of pressure abo

There are several bright coron
and in the neighbourhood of on
length 4231, there seem to be t
absorption lines visible in the spec

III. *Spectrum of the Sun's Limb a*
after the end of the exposure of
corona, the image of
unexp

It was found later that the faintness of the light was caused by a dark glass in front of the eye-piece, which was used for viewing the image on the slit. This was needed in the first exposures, but should have been removed by turning the hinged glass aside. It is evident from the photographs that the image was improperly adjusted in consequence of the faintness of the light; there is no impression on the plates.

The results obtained with the four-prism spectroscope may be summarised as follows: Five photographs of the spectrum of the vapours near the sun's limb at a fixed point, and a photograph of the spectrum of the corona at two points widely separated near the sun's limb.

§ 25. *The Photographic Camera with Large Objective Grating.*

Visual observations of the green coronal ring made at Pulgaon, India, 1898, January 22,* convinced me that the ring could have been photographed with the objective grating and telescope then used. Accordingly preparation was made to attempt a photograph with a large grating at Algiers. For this purpose, use was made of a plane grating by Rowland, 14,438 lines to the inch on a ruled surface $5 \times 3\frac{1}{2}$ inches, fitted on an axis in front of a telescope of focal length 68 inches and aperture 4 inches. The grating is a very brilliant one, and is ruled on an unusually fine-grained piece of speculum metal. The object glass is an excellent one by Cooke and Sons. Both of these belong to the splendid spectroscopic installation arranged by the late Professor Piazzi Smyth, with the aid of contributions from the Government Grant. The installation is now set up at the Cambridge Observatory, having been put at my disposal for spectroscopic investigations by the Royal Society. I am thereby put under a great obligation to the Society, and I venture to take this opportunity of making acknowledgment of it.

In the recent eclipse the sun was about as far to the north of the celestial equator as it was to the south in the Indian eclipse of 1898; accordingly the grating and telescope could be mounted in almost the same relative positions in Algiers as in India; it was only necessary to reverse the positions along the polar axis, and arrange that the telescope pointed towards the south pole instead of the north. Accordingly the instruments were mounted so that the telescope was parallel to the earth's axis and pointed downwards towards the south pole. For the purposes of taking photographs this position was extremely convenient.

A strong wooden bridge or yoke was fitted to the object glass end of the tube of the telescope, and projected in front of the object glass

* 'Roy. Soc. Proc.,' vol. 64, p. 58; and 'Mon. Not., R.A.S.,' vol. 58, App., p. (58).

at such a distance from it that the grating could be mounted free to turn on a spindle passing through the sides of the yoke at right angles to the collimation axis. A small brass cup or socket was attached to the middle point of the yoke so that it lay in the axis of collimation, and it was made the lower bearing, by which the whole instrument was supported on a pointed pivot, fixed, with a small amount of freedom for adjustment, on a low pillar of brickwork. The upper end of the tube of the telescope rested on antifriction rollers, supported on the west side of the higher pillar of brickwork, which also carried the four-prism spectroscope. Thus the polar axes of the two instruments, viz., the objective-grating camera and the mounting of the four-prism spectroscope, were side by side; and it was not a difficult matter to link together the two mountings by means of a connecting rod, so that the same clockwork should drive both. Each mounting was connected by slow motions with the one clock-driven sector, and so each could be adjusted relatively to the sun without disturbing the other. The arrangement worked admirably.

The light of the corona was incident on the grating at an angle of about 55°, and the diffracted beam utilised in the telescope left the grating at an angle of about 13° 40′. In this position of the grating the green of the second order was used and the magnifying power of the grating was a little greater than one-half, so that the coronal ring was distorted into an ellipse, in which the major axis was perpendicular to the length of the spectrum and parallel to the direction of daily motion.

The axis of the instrument having been adjusted to parallelism with the earth's axis, it remained only (i) to set the grating so that the coronal ring should appear in the middle of the field, and (ii) to focus the instrument. Neither of these operations could be done satisfactorily before the eclipse, that is, before the diminishing crescent of the sun made it possible to recognise the exact position of the spectrum in the field of view. Ten minutes before totality the dark lines were indistinctly visible in the spectrum, and a glance showed me that I had had an extraordinary stroke of good fortune in the rough setting of the grating, an operation which had been done by turning the grating till I thought the colour of the green was about right for the background of the magnesium lines. For the lines were only slightly displaced from the centre of the field, and the adjustment for the part of the spectrum required in the photograph was practically correct to a nicety. Accordingly no further adjustment was attempted. Two minutes before the beginning of totality the crescent was fine enough to show the dark lines in the spectrum very distinctly, a somewhat bewildering array of interlacing elliptical crescents, and the focussing was accomplished with ease. Mr. Henn then took charge of the instrument, and put a dark slide in position,

and adjusted the exposing shutter. I am very much indebted to him for his admirable precision in carrying out the programme of exposures.

The programme was carried out as follows:—

Three plates were exposed.

Plate X, 1. For the brightest chromospheric lines, at the beginning of totality—a short exposure, about $1\frac{1}{2}$ seconds.

This plate was to be exposed at the signal "Start," given by Professor Turner, and was to be closed between the time-keeper's calls "one" and "two."

It was actually exposed at the signal "Start," and closed at the time-keeper's call "three." The time-keeper found that the first beat of the metronome after "Start" came so soon that he did not call "one," but called the next beat "two" without calling "one" at all. The exposure was thus probably $2\frac{1}{2}$ seconds.

Plate X, 2. For the green coronal ring—a long exposure, about 40 seconds.

This plate was to be exposed as soon after Plate X, 1 as the change of plate holders would allow, and was to be closed at the call "fifty-five.

It was actually exposed at "nine" and closed at "fifty-five," and thus had an exposure of about 46 beats.

Plate X, 3. For the Fraunhofer lines immediately after the end of totality for comparison with any chromospheric lines that might appear on Plate X, 1.

This plate was to be exposed when I gave the signal "Now," and was to be closed 1 second later.

It was actually exposed at "seventy-one," and closed at "seventy-two."

Results.—The Plates X, 1 and X, 2 show faint images, but have not been examined carefully yet; a cursory examination shows that (*a*) only a single chromospheric line appears on X, 1; and (*b*) continuous spectrum appears on X, 2, but no *marked* coronal ring is discernible.

Plate X, 3 is a strong spectrum, showing the curved Fraunhofer lines between wave-lengths 5050 and 5460; the linear dispersion on the plate is, roughly speaking, 5 tenth-metres per millimetre.

Remarks.—In an eclipse with longer duration of totality, the procedure here described should give good results for the green coronal ring. The plates used were Edwards's Isochromatic Snapshot plates. It should be remembered that the effective aperture of the camera, viz., a little less than F/17, was rather dangerously small.

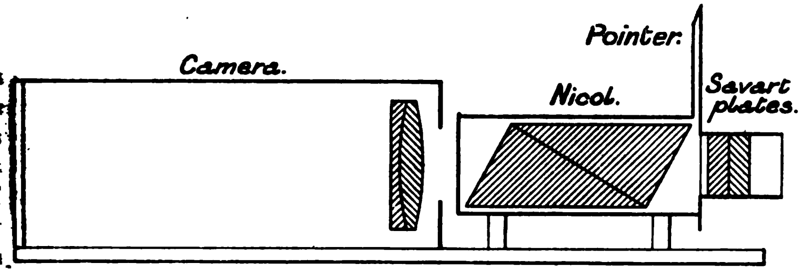
§ 26. *The Polariscopic Camera (Savart Plates and Nicol Prism).*

The glimpses of the corona that I was fortunate enough to get in India in 1898 through a small Savart polariscope convinced me that that instrument, if properly used, would give just the information that is wanted to decide some of the perplexing points that still survive in the spectroscopic and polariscopic study of the corona. The chief objection is that the phenomena are far too complicated to study by eye observations in the short time at one's disposal in an eclipse. Here is a case in which photographic methods should certainly be adopted if possible. Shortly after my return from India in 1898 I made some experiments to test the feasibility of photographing Savart's bands, and met with such promising success that no doubt was left in my mind that a photographic record of the distribution of Savart bands over the corona would give good results in supplementing the work which Professor Turner has in recent eclipses been carrying out in studying the polariscopic phenomena of the corona. Accordingly when I was asked to take part in the observations of the eclipse at Algiers, it seemed well to make arrangements to prepare a polariscopic camera.

Professor J. J. Thomson very kindly put two large Nicol prisms at my disposal. The aperture of these prisms is $1\frac{5}{8}$ inches. It was thus possible to use a lens of a focal length of about 3 feet, if suitable Savart plates could be found. On making the necessary calculations I found that the plates would have to be 15 mm. thick, cut in quartz at 45° to the axis of the crystal. A pair of such plates would give bands of the desired closeness, viz., about 10′ apart, instead of the usual 1° or 1° 30′. Fortunately Mr. Hilger was able to cut a slab, from the sloping top of a quartz crystal that I had in my possession, large enough to make two plates, each 14 mm. thick, of circular section, and with a diameter of 39 mm. ($1\frac{1}{2}$ inches). The whole slab was worked and polished with plane parallel surfaces, so as to secure equality of thickness, and was then cut into two parts, which were combined in the usual manner.

The figure shows diagrammatically the arrangement of the camera with the Savart plates and Nicol prism in front. The lens was a $3\frac{1}{2}$-inch lens of focal length 40 inches. The aperture was reduced to $1\frac{1}{2}$ inches, or approximately F/27 for central pencils. The Savart plates were fixed to the Nicol prism so that the bands were parallel to the plane of polarisation of the light transmitted by the Nicol. The whole system was arranged so that it could be rotated on its axis into any desired position, and a pointer was provided so that the position could be read off a large circle.

In discussing with Professor Turner the arrangements for the various items in the programme of observations to be carried out, he



very kindly suggested that the parts of this apparatus should be put into one of the compartments of the "double tube" alongside of the other polariscopic apparatus which he had himself arranged. I fell in with this suggestion very gladly, and the parts were taken to Algiers to be fitted there. It required very careful arrangement to get the two lots of apparatus into the tube, but in the end it was successfully accomplished, and Professor Turner made the exposures for the Savart camera simultaneously with those for his own polariscopic and other cameras. The pictures obtained with the Savart camera are on the same plates with the pictures obtained with Professor Turner's double image polariscopic camera.

The general procedure with the Savart camera was to be as follows:—The Savart and Nicol were to be rotated until the bands due to the plane polarisation of the sky in front of the corona were extinguished, and photographs of the corona were to be taken. But it was not possible to look through the camera itself in order to make the adjustment "to extinction," for this would have interrupted the exposures for all the other instruments in Professor Turner's charge. Accordingly a subsidiary Savart polariscope was provided, which I may call the visual Savart to distinguish it from the camera Savart. The visual Savart was set up in my hut, with pointer and graduated circle attached, and the zero and numbering of the scale were adjusted so that the readings corresponded with those of the camera Savart, account being taken of the fact that the sky was seen in the camera by reflection from the cœlostat.

The programme of exposures was as follows:—

1 second, 5 seconds, 20 seconds, 5 seconds, 1 second.

The first two were made with an arbitrary setting of the Savart, and the setting chosen was approximately that which would correspond to extinction of bands due to vertical polarisation. Meanwhile I had determined the plane of polarisation of the sky in front of the corona by observations with the visual Savart, made immediately after the exposures with the four-prism spectroscope were so far completed that the long exposure for the corona spectrum was begun, viz., 6 seconds

after the signal "Start." Mr. Potter, standing by me, received the reading resulting from my observations, and carried it to Professor Turner's hut, and Major Kingsley Foster adjusted the large Savart to the corresponding reading, and the third exposure was begun.

The camera Savart was left with the pointer at 10° for the rest of totality, no attempt being made to test the permanence in the position of the plane of polarisation of the sky as the total phase of the eclipse passed over.

Results.—The resulting photographs show strong bands over the corona. A cursory examination discloses the following results:—

No. 1. 1 second. Coronal extensions discernible as far as 10′ or 11′ from the limb.

No atmospheric bands visible, but obvious bands over the corona.

No. 2. 5 seconds. Coronal extensions as far as 35′ from the limb.

The planet Mercury appears on the plate.

Atmospheric bands are visible, very faint, on the following side of the sun, extending 4° 40′ from the limb, but are not visible on the preceding side near Mercury.

No. 3. 20 seconds. Coronal extensions 63′ in N*p* streamer.
" " " " 52′ in S*p* streamer.
" " " " 70′ in N*f* streamer.

Mercury very strong.

Atmospheric bands visible to the edge of the plate on both sides. Strong bands over the corona.

No. 4. 5 seconds. Coronal extensions 35′ from the limb.

No atmospheric bands visible on either side.

Nos. 5 and 6. Not examined.

The existence of the image of Mercury on the plates will be of great value in determining orientation in the polariscopic phenomena as well as in the corona.

The strong bands over the corona indicate that a considerable portion of the light is polarised. There are irregularities in the bands which seem likely to afford interesting study just in the way that was anticipated.

The atmospheric bands faintly visible on the plates are almost certainly due to imperfect adjustment of the Savart to extinction, arising from zero errors, &c.; they might be due to a change in the position of the plane of polarisation of the sky after the initial setting of the Savart. In any case they are very feeble, and it is clear that it would be well, if ever the experin [illegible] o *aim* at imperfect adjustment

so that the atmospheric bands may be in opposite phase—*i.e.*, with black central band—to the coronal bands.

By a very fortunate accident just such an imperfection has arisen in the case of the plate No. 3, for the bright bands on the corona fall on dark atmospheric bands. It might be that the curvature of Savart's bands, which theoretically exists, misleads one; but a tolerably careful examination of the faint bands shows them to be sensibly straight in the limited field dealt with, and the antagonism of the bands leaves no possible doubt that the bands seen on the corona are due to the polarisation of the corona.

It is difficult to reconcile the marked polarisation evidenced in this investigation with the absence of Fraunhofer lines in the spectrum of the corona.

Across the dark moon no atmospheric bands are discernible, and there appears to be no doubt that photographically the dark moon is darker than the sky. These are points that need explanation. An investigation of the real facts would be difficult, but none the less interesting; for the idea suggested by much of the evidence along different lines is that some of the light which is usually attributed to the sky may come from beyond the moon. For instance, is a milky sky on a moonless night simply the result of starlight scattered by the processes producing scintillation, or are other causes at work?

§ 27. *Atmospheric Polarisation.*

Preparations had been made that a systematic survey of the polarisation of the sky should be undertaken during the eclipse, with a view to determining the plane of polarisation in various quarters of the sky, a more precise knowledge of the general distribution of polarisation being needed for the explanation of some of the anomalies that appear to have been observed with respect to the atmospheric effects in previous eclipses.

Nine Savart polariscopes were mounted in similar turning tubes, provided with pointers and graduated circles, and attached to wooden stands. The stands were arranged so that each carried two polariscopes; one pointed to the horizon, the other to a point 30° above the horizon. The four stands were fixed on the top of a tall box on the balcony of the equatorial coudé which M. Trépied had kindly put at our disposal. The polariscopes were directed towards the four quarters of the sky, N.E., N.W., S.W., and S.E. During the eclipse the sun was at an altitude of 30°, and only a few degrees north of west; thus the polariscopes were directed to points nearly symmetrically disposed with regard to the sun. All the Savart plates were fixed relatively to the Nicol prisms, so that the bands were parallel to the plane of polarisation of the light transmitted by the Nicols.

The ninth Savart polariscope was mounted in a turning tube with pointer and circle complete, on a board which was screwed to an inclined block on the western doorpost of the hut which contained my spectroscopic apparatus. It was pointed towards the corona, and was in fact the visual Savart used by myself in the way described in the previous section (p. 363) for determining the position of the plane of polarisation of the light from the sky in the immediate neighbourhood of the corona, so that the camera Savart could be adjusted accordingly. The polariscope had been left in position with the bands horizontal and the pointer at 90°. Six seconds after the beginning of totality I left the spectroscope and looked through the polariscope. The eclipsed sun was slightly (perhaps 5°) to the north of the centre of the field of the Savart. The bands were seen fairly strong over the whole field of view, the central band being black. The Savart was then turned counter-clockwise, until the bands were extinguished. The reading was found to be 9° on the scale arranged to correspond with that on the large Savart in Professor Turner's hut. This reading showed that the plane of polarisation of the sky in front of the corona was inclined at an angle 4° to the vertical read counter-clockwise from the vertex. (There is possibly a zero error; it has not yet been determined.) When the atmospheric bands were extinguished faint traces of bands were seen over the corona, but much less strong than in the Indian eclipse.

I examined the polarisation of the sky in the zenith about 10 seconds after the end of totality, and found that the plane of polarisation passed through the sun.

Mrs. Newall undertook the charge of the eight other polariscopes, which were arranged as described above, and her programme for the eclipse was to turn each instrument, so that the Savart bands disappeared, paying attention to the direction of turning as follows:—If the band system had a white central band the polariscope was to be turned clockwise. If the system had a black central band it was to be turned counter-clockwise. The instruments were then to be left untouched, and the positions of the pointers were to be written down at leisure after the eclipse. Mrs. Newall devoted herself very diligently to setting the instruments under very varied conditions on the days preceding the eclipse, and so expert did she become that she was able to make the necessary settings of all eight polariscopes in about 42 seconds. If the polarisation was weak, about 50 seconds were needed. In the following table, taken at random from her notebook, the figures in the upper line are the readings of the pointers of the various polariscopes when the settings were made in a leisurely manner; those in the lower line are the readings when the settings were made "racing." "Hor." refers to the horizontal polariscope; "30°" to that which points upwards :—

S.E.		N.E.		N.W.		S.W.		
Hor.	30°	Hor.	30°	Hor.	30°	Hor.	30°	
106°	74	168°	178	170°	121	114°	136	Leisurely.
104	74	164	176	164	122	116	135	Racing.

The following readings show that in a leisurely setting the observation of extinction of the bands is satisfactory.

1900. May 24. Ten settings for extinction of bands in the middle of the field—16°, 15°, 16°, 12°, 16°, 17°, 16°, 17°, 17°, 16°. Mean 15°·8. It is thus clear that the "racing" settings give results of about the same order of accuracy as the leisurely ones.

In the eclipse itself, the observations were made on the balcony of the equatorial coudé, and unfortunately, on account of other noises, the signal, "Stand by," announcing that the beginning of totality was approaching, was not heard by Mrs. Newall, who was standing in the doorway of the balcony with a view of protecting her eyes from the sunlight till the last moment. Nearly half of the duration of totality had passed before she came into the open, and heard the twenty-eighth beat of the metronome being called. Going at once to the polariscopes she began to adjust them; she had set four of them "to extinction," and had nearly completed the setting of the fifth, when sunlight reappeared. With regard to the last observation, Mrs. Newall noted an interesting point. She had nearly completed the setting to extinction when the bands suddenly became bright again, with black centre, and she turned the polariscope counter-clockwise, from somewhere near the reading 20°, and had nearly set again to extinction before realising that totality was over. The reading of the polariscope was then found to be 345°.

The actual circle readings recorded immediately after the eclipse were as follows, and it was noted that the bands were very faint:—

S.E.		N.E.		N.W.		S.W.
Hor.	30°.	Hor.	30°.	Hor.	30°	
105°·0	94°·1	324°·8	340°	? 20° ±		

[345° after return of sunlight.]

These require small corrections for the index errors, which can only be determined after the instruments return from Algiers, but it may be provisionally stated that the angles made by the plane of polarisation with the vertical, read from the vertex clockwise, are as follows:—

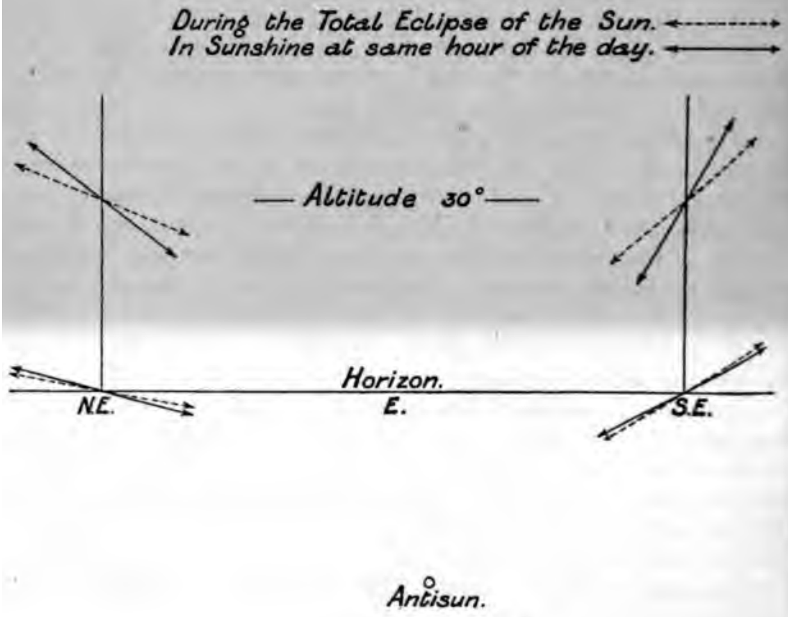
S.E.		N.E.		N.W.		W.
Hor.	30°.	Hor.	30°.	Hor.	30°.	Over corona.
60°	49°	280°	295°	? 305° ±		356°

[From my own observations.]

Comparison with the observations secured on other days at about the same time of day as the eclipse, viz., 4.30, may be summarised graphically as in the accompanying figure :—

Polarisation of the Sky. Algiers, 1900, May 26–28.

Plane of Polarisation.



The results are of considerable interest in their bearing on the well-known peculiarities in the phenomena of the polarisation of the sky in the neighbourhood of "neutral points."

It is a great satisfaction to be able to record these observations, for though they are incomplete, yet they were successfully carried out in spite of circumstances which would have upset many a practised observer; and the regret is all the greater that Mrs. Newall had to pay such a forfeit for her resolution, for she did not get more than a glimpse of the eclipse.

Of the nine Savart polariscopes used in these observations, four were lent to me by the Council of the Royal Astronomical Society, and three by Professor Lewis, through Mr. A. Hutchinson, of Pembroke College, Cambridge, who had arranged to come to Algiers, and had volunteered assistance in the observations recorded in Section 25 of this Report, but was unfortunately prevented at the last moment, by illness, from coming.

§ 28. *General Observations.*

The general darkness during totality was about the same as in ndia.

The dark moon did not appear so strikingly coal black in Algiers s it did in India. This is curious when considered in connection vith the fact that the polarisation of the sky in front of the corona vas much stronger in India than in Algiers.

Round the limb the brightness appeared relatively much greater in lgiers than in India. The breadth of the bright ring was estimated s 2′ to 3′; the decrease in brightness along the radius was very brupt at this distance from the limb; at 4′ or 5′ from the limb a ower level of brightness was reached and thence outwards along the quatorial streamers the decrease in brightness was small up to points bout 2° from the centre.

My impression of the streamers, recalled from a very vivid memory f the picture in my mind, is that the double streamer on the preceding ide of the sun certainly extended beyond Mercury, and there was a imilar extension on the following side. The latter extended for some listance as a broad streamer with nearly parallel edges.

I used a telescope of $3\frac{1}{2}$ inches aperture and of 29 inches focal ength for viewing the corona direct. The instrument was merely lamped to the walls of the hut. I was able to focus the instrument arefully, and devoted some moments to examining the corona immediately outside the large prominence in the S*p* quadrant. The prominence appeared double, one side having the form of a tapering column projecting radially from the limb, and the other appearing in cloud-like floating forms, both parts being of a wonderful rose colour. In the corona I was disappointed to find no striking signs of arches over the prominence. The only fine structure visible in the corona were a few interlacing wisps crossing one another, presumably in the part where the two streamers on the preceding side of the sun crossed one another in diverging from one another.

The shout that is stated to have risen from the Arabs in Algiers was heard by me as I exposed the plate for the spectrum of the corona, that is, as Mr. Wyles called "six." Algiers lies just a little more than a mile in a direct line from the Observatory. It seems probable that the shout was uttered at the same instant as Professor Turner's signal "Start," and announced that the totality had begun at Algiers.

"Solar Eclipse of May 28, 1900. Preliminary Report Expedition to the South Limit of Totality to obtain graphs of the Flash Spectrum in High Solar Latitudes J. EVERSHED. Read at Joint Meeting of the Roy Royal Astronomical Societies, June 28, 1900. MS. r July 16, 1900.

This expedition was one of those organised by the Joint Pe Eclipse Committee of the Royal Society and the Royal Astro Society, funds being provided from a grant made by the Gov Grant Committee.

The following were the principal objects which I had in arranging the expedition:—

To obtain a long series of photographs of the chromosph flash spectrum, including regions of the sun's surface in mid-la and near one of the poles.

The photographs to be obtained with a long focus prismatic on a large scale, in order to be able to discriminate clearly high levels and low levels in the chromosphere.

The photographs to include as much as possible of the ult region of the spectrum, for the purpose of verifying the results o with a smaller instrument in 1898, and to give more accurat of the wave-lengths determined from those results.

This report may be conveniently divided into the followi sections, viz.:—

1. Selection of observing station.
2. Instruments, methods of mounting, and general arrange camp.
3. Narrative of expedition, and observations made on the the eclipse.
4. Results.

(1) *Selection of Observing Station.*

A consideration of the conditions under which the lowest la the chromosphere are presented during a total solar eclipse that a very great advantage would be gained by selecting a situated near the limit of the zone of total eclipse, where t internal contacts would be separated by a small angle on th limb.

At such a station the motion of the moon relative to the sun direction approximating to parallelism with a tangent to th limb at the points of internal contact, the result being that the sively shallow layer ... so-called "flash spectr

occulted by the moon comparatively slowly. Much more time is therefore available for taking a series of photographs than is the case at stations near the central line of the eclipse, where the moon's motion is at right angles to the layer, and opportunities for obtaining photographs of the very lowest strata are reduced to a fraction of a second only at each internal contact.

I decided therefore to choose some point situated well within the zone of total eclipse, but so far from the central line that the two internal contacts would be separated by an angle of about 39° on the sun's limb. This would give a duration of totality equal to one-third that at the nearest point on the central line; and the time available for photographing the flash spectrum would not be less than 30 seconds. At mid-eclipse the moon's limb would overlap the photosphere about 1″, so that even at that time the flash spectrum layer would not be entirely hidden.

Under these circumstances, also, one of the contacts would take place at, or very near to, one of the poles of the sun, the other being in latitude 51°. A succession of photographs taken during totality would therefore give a series of images of the flash spectrum ranging from solar latitude 51° to the pole.

In selecting the most suitable station, dryness of climate was considered to be the most important factor for securing extension of the spectra in the ultra violet; I therefore selected Algeria in preference to Spain, although the altitude of the sun would be less in the former country.

The best position in Algeria for realising the greatest solar altitude was a point on the coast west of Algiers, and on the southern border of the eclipse track. This region was therefore decided upon at the outset, and in order to realise the favourable conditions mentioned above, two stations were selected provisionally beforehand, and for these Dr. Downing kindly computed for me the durations of totality according to the data used by the Nautical Almanac Office.

The first station, near to the village of Zeralda, was found by him to have a duration of 45 seconds, *i.e.*, more than one-half the central line duration. The other station, three miles further south, and near to Maelma, was computed to have a duration of 29·5 seconds with a possible error of ± 10 seconds.

As the required conditions would, apparently, be very nearly fulfilled at the latter station, I decided to place my camp either at that precise spot, or at some point situated on a line passing through it, and parallel to the direction of the shadow track in that region.

The actual station eventually chosen was 6·5 kilometres distant from the station near Maelma, in a direction bearing West 25° North. Here it was estimated that totality would last 30 seconds. Unfortunately, as the event proved, the value of the diameter of the moon adopted by

our Nautical Almanac Office is too large, and the limits of error given above were very misleading. Instead of a duration of 30 seconds, the eclipse at my station was never quite total.

(2) *Instruments, Methods of Mounting, and General Arrangement of Cam*

It was my intention originally to take out a fine 18-inch silver-on-glass concave mirror made by the brothers Henri, which was given to me by the late Mr. Ranyard. This mirror, having a focal length of 117 inches, would have given images on a scale of 1·08 inch to the sun's diameter

Many experiments were made with this mirror to determine the amount of aberration produced on star images at considerable distances from the axis, and with various apertures. It was found that when the ratio of aperture to focal length did not exceed 1/15, good images were obtained 4° from the normal axis, the aberration being very slight.

As this would admit of a very wide range of spectrum being photographed with good definition throughout, I decided to adapt my large reflecting telescope for eclipse work. Owing, however, to the difficulty of obtaining a prism of large angle and not less than 6 inches aperture, I had, most unfortunately, to abandon this scheme and construct a much smaller apparatus.

Through the kindness of Dr. Rambaut I eventually obtained a fine 4-inch prism of light flint glass and 45 degrees angle. This prism, which was generously placed at my disposal by Sir Howard Grubb, proved most efficient for the work, although I was unable to utilise the full aperture.

Three spectrographs were finally made: a reflecting prismatic camera of 3 inches aperture and 74 inches focus, an ordinary prismatic camera of 2 inches aperture and 47 inches focus, and a quartz prismatic camera of 1 inch aperture and 24 inches focus. These were mounted together inside an observing hut, and were supplied with light from a 12-inch cœlostat.

The Reflecting Prismatic Camera.

This was an ordinary reflecting telescope with a mirror of 9 inches aperture and 74 inches focus. It was fitted with a strong wooden tube, adapted for carrying two large prisms near the upper end. The prisms used were the 4-inch 45-degree prism, lent me by Sir Howard Grubb, and a 3-inch 60-degree prism lent me by Dr. Common. These were mounted eccentrically within the tube, in such a manner that the incident light, after passing through the prisms, made an angle of about $1\frac{1}{2}°$ with the normal axis of the mirror. After reflection from the mirror the rays returned over the upper surface of the 60-degree prism, and came to focus about an inch outside the end of the tube

The end of the tube was closed by a block of wood having an aperture [illegible] inches long by 3 inches wide, a little above the middle. Outside this a long slide was arranged, at right angles to the telescope, and bolted at the upper end to two stay rods attached to the telescope near the mirror.

A plate holder, 3 feet long by 10 inches wide, taking two plates 8½ inches square and four plates 8½ by 4¼ inches, was arranged to move along the slide by means of rackwork and a pinion wheel. One revolution of the pinion moved the plates 2·13 inches, whereby four images could be obtained on the square plates and two on each of the narrow ones; the sixteen images all being equal distances apart and symmetrically placed on the plates. The revolutions of the pinion wheel were controlled by a spring catch acting on the crank handle, and holding it firmly in position after each revolution.

The whole slide, carrying the plate holder, &c., was attached to the telescope in such a way that the distance of the plates from the mirror could be varied a small amount for focussing.

The tube of the instrument was firmly bolted down to the sloping side of a solid pier of stone and cement, built up within the observing hut near the north end. It was adjusted so that the plane of dispersion of the prisms was in a meridian passing through the cœlostat, and inclined to the prime meridian 68° (the hour angle of the sun at mid-eclipse). The dispersion was therefore in a north and south direction. The internal contacts were computed to occur near to the south point of the sun, and on either side of it. The centre of the flash spectrum arcs was therefore midway between the edges of the spectrum in the photographs obtained at mid-eclipse.

The 2-inch Prismatic Camera.

This instrument was the same which I employed successfully at the Indian eclipse in 1898, excepting that it was fitted with a specially corrected lens of 47 inches focus instead of the visual objective previously used. The images were therefore on a somewhat larger scale, and larger plates were used.

The sliding plate holder, constructed on the same lines as the larger instrument already described, was made to hold three plates, 6½ by 4¼ inches, placed lengthwise in the holder; and the crank handle moving the slide was arranged to stop at each half revolution, moving the plates 1·12 inches between each exposure.

The two 60° prisms of this instrument are made of specially selected crown glass, and are exceptionally transparent for ultra-violet rays.

The total deviation of the two prisms being approximately equal to that of the reflecting spectrograph (about 80°) the tubes of the two in-

truments were arranged nearly parallel, the 2-inch spectrograph being crewed to the side of the reflector with its aperture alongside that of he latter. The camera end with the sliding plate holder was at the ower end.

The Quartz Prismatic Camera.

This was rigged up while in camp, as it was found that a small portion of the cœlostat mirror was available to supply light. It consists of two double quartz prisms of 60° and 40° angle respectively, each prism having 1¼-inch square faces; and a single quartz lens of 24 inches focus. It was screwed on the top of the 2-inch spectrograph with its aperture just within the elliptical beam of light from the cœlostat.

My brother arranged a very convenient exposing shutter, which he was to open near mid-eclipse for a single exposure of 10 seconds.

Methods of Focussing.—All three spectrographs were approximately focussed by taking a series of photographs of the spectrum of Venus. Having determined the focus of the reflecting prismatic camera in this way within very narrow limits, I used this instrument as a collimator for the 2-inch spectrograph, removing the large prisms, and adjusting a slit in the position occupied by the plates when photographing Venus. The 2-inch instrument was attached to the wall of the hut, with its aperture inside the tube of the reflector, and directed towards the mirror. With the north door of the hut widely open, the slit was illumined by light from the sky, and a series of photographs was obtained of the Fraunhofer spectrum.

For some reason the focus was not so sharply defined, and the definition of the lines was not so good as in photographs I had obtained by the same method before leaving England.

A third method was therefore tried. After having adjusted the 2-inch spectrograph in its correct place, photographs were obtained of the sun itself on Sandell triple plates; the focus being determined by the images which were most sharply defined along the edges.

A final method, which was adopted for the two larger instruments, was to adjust the focus visually during the eclipse itself, using the Fraunhofer lines, which become sharply defined shortly before totality

Programme of Exposures.—The two larger prismatic cameras were each to have sixteen exposures made simultaneously, by removing a plate of aluminium from the common aperture of the two instruments. The first, second, fifteenth, and sixteenth exposure were to be of about 1 second duration each, and the remaining exposures of 2 seconds duration, excepting the exposure nearest to mid-eclipse, which was to have 10 seconds.

The quartz prismatic camera was to be exposed near mid-eclipse also for 10 seconds.

These relatively long exposures were designed to secure density in the ultra violet, at the risk of over-exposing in the region near G.

Having ascertained by rehearsing that the time required for exposing the plates would be about 90 seconds, I arranged that the first exposure should be timed at 45 seconds before the computed time of mid-eclipse The succeeding exposures were to follow each other at the shortest intervals, turning the handles deliberately, and allowing ample time for shake to subside before each exposure.

I was to use my discretion to some extent in making the long exposure at mid-eclipse, but otherwise I intended to be guided solely by the chronometer.

The exposures were to be made by myself, standing at the north door of the hut and facing the large spectrograph. I used my left hand to work the exposing shutter, and my right to rack the plates forward in the slide.

My brother, sitting on his bed in the hut, was to move the plates of the 2-inch spectrograph, turning the handle half a revolution after each exposure. He was also to expose the quartz spectrograph at a signal from me.

The Cœlostat.

A 12-inch cœlostat was used to supply light to the three spectrographs in the hut. It was placed about 6 feet from the north-east corner of the hut, and was arranged to reflect the sun in a meridional plane; the angle between the incident and reflected beam being in this case a minimum, viz., declination of sun × 2. The reflected beam was in a direction W. 30° S., and was directed upward at an angle of $3\frac{1}{2}°$ with the horizontal.

The instrument was mounted on a steel plate fixed on the top of a masonry pier, and about 3 feet from the ground. The plate had a straight channel cut in it just wide enough to take the ends of two of the four levelling screws, the other two resting on the planed surface of the plate.

With the plate placed approximately level and the channel approximately north and south, the whole instrument could be shifted bodily north or south without disturbing the adjustments of the axis in altitude and azimuth. In this way the adjustment of the beam of light with respect to the apertures of the three spectrographs was very easily managed, and the cœlostat could be shifted about to suit the varying declination of the sun on occasions, previous to the eclipse, when it was desired to observe the spectrum and adjust the spectrographs.

The cœlostat was provided with slow motion independent of the driving gear, and this was controlled from inside the hut by means of a rod, 8 feet long, which my brother laboriously cut from a 3-inch plank.

The driving clock was bolted down to the north end of the cœlostat pier. It was driven by a weight suspended from a large tripod erected near.

The $3\frac{1}{4}$-inch Telescope.

In addition to the photographic instruments I had a $3\frac{1}{4}$-inch equatorial telescope, and a high dispersion solar spectroscope. The telescope was mounted on a packing case outside the hut, and was useful in a variety of ways. With the spectroscope attached it was used for the observation of solar prominences on the day of the eclipse, and on several other occasions.

The Observing Hut.

This was a rectangular wooden shed, the sides enclosing a space 14 by 9 feet and 6 feet high. The sloping roof was covered with boards up to about 1 foot from the centre beam. A large sheet of canvas was stretched above the boards, leaving an air space between: this allowed of the free circulation of air between the canvas and the wood, and was designed to prevent the interior from becoming unbearably hot during the day.

This arrangement, however, was anything but water-tight, as we found to our cost during a spell of bad weather. We subsequently procured a large rick cover, which was tied securely over the canvas and down to the ground on the weather side of the hut.

This hut was designed by my brother for the accommodation of the somewhat unwieldy reflecting spectrograph and two camp beds. The frame was constructed by him before leaving England.

The accompanying ground plan shows the general arrangement of the camp.

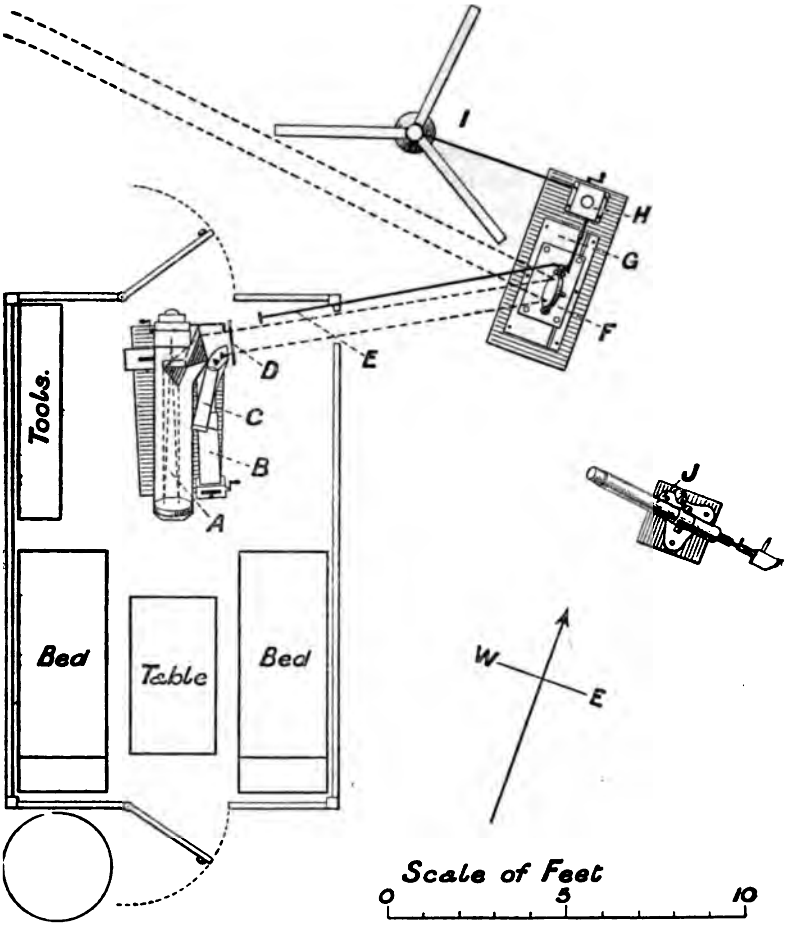
(3) *Narrative of Expedition and Observations made on the Day of the Eclipse.*

The expedition, consisting of my brother (Mr. Harry Evershed) and myself, left England on April 30th, and travelling *via* Paris and Marseilles arrived at Algiers on May 3rd.

At Algiers we received every attention and assistance from the British Consul-General, Mr. Hay Newton, to whom our acknowledgments are due. He procured for us a letter from the Préfecture to the Mayor of Maelma, ordering the latter to assist us in every possible way in selecting a site for our camp.

We also received assistance and advice from M. Trépied, of the Algiers Observatory, who very kindly called at our hotel and discussed with us our plan of operations.

PLAN OF OBSERVING STATION, MAZAFRAN CAMP.



A. Reflecting spectrograph.	F. Cœlostat.
B. 2-inch spectrograph.	G. Planed steel plate with channel.
C. Quartz spectrograph.	H. Driving clock.
D. Exposing shutter.	I. Tripod for weight.
E. Cœlostat slow-motion handle.	J. 3-inch telescope and spectroscope.

Having obtained letters of introduction to some landowners in the district we intended to occupy, we went at once to the village of Zeralda, about 20 miles west from Algiers, and making this our head-quarters for a few days we explored the neighbouring country.

The people to whom my brother had letters received us with the greatest civility, and we desire to mention in particular M. Buloff,

dministrator of the estate of the Comte de Perigord, and formerly 'rofessor at Stonyhurst. This gentleman was much interested in our ıission, and we are practically indebted to him for giving us a letter o a colonist, M. Alvado, upon whose farm near the sea coast we ventually found an excellent site for our camp.

It was evident at the outset that the wild hilly region near the illage of Maelma would be more difficult of access than the country ırther west near the coast. Maelma itself we found to be poverty-tricken and unpromising. The mayor, whom we found in his mairie usy with the coming elections, was obliging enough to *visé* our ocument from the Préfecture; or rather he got his secretary to do o, being unable himself, apparently, to read or write. Having had ur letter duly *viséd* we abandoned Maelma, and proceeded to the Iazafran River, near the coast, to conclude negotiations already entered ıto with Alvado.

These presented no difficulty, for M. Alvado was "un homme très rave," and offered us his whole territory, vineyards or cornfields, for ur camping-ground. We were, however, limited in our choice to a ne bearing West and 24½ degrees North from Maelma, in order to ecure the same duration of totality as had been computed for that place.

The position finally chosen was near to the mouth of the Mazafran River on the east side, and about 1 kilometre from the sea.

The position of the Mazafran bridge, about 400 metres distant, was ascertained from a recent survey to be

North latitude	36°	41′	35″
East longitude	2	48	30

The position of the camp, which my brother carefully determined by triangulation from the bridge, was as follows :—

North latitude	36°	41′	47″
East longitude	2	48	41

It was 17 metres above sea-level, and 6·5 kilometres from the station near Maelma, in a direction bearing West 25° North.

As the direction of the shadow track in this region was ascertained to be 24° 39′ North of West, we concluded that the above position would be safe for a duration of 30 seconds of totality.

Having settled all preliminaries we returned to Algiers to arrange for the transport of the instruments. This was effected without difficulty by means of the light railway recently constructed from Algiers to the Mazafran.

On May 9th we retur[redacted]do's farm, and the next day the work of erection was

Our hut, which was to serve as sleeping and living room as well as observatory, we had ready for occupation the same evening.

During the fortnight preceding the eclipse, our time was fully occupied in erecting and adjusting the three spectrographs, cœlostat, and other instruments, and in taking trial photographs for determining focus. We also made daily observations of the sun with a sextant and artificial horizon for determining time, and checking the rate of a chronometer which we had hired for use in our camp. Being far from any telegraph station in direct communication with Algiers, we were obliged to depend entirely on observation for our time on the day of the eclipse. Working with instruments of very second-rate quality, my brother usually succeeded in determining local time within one or two seconds of error, taking the mean of a day's set of observations (usually employing the method of double altitudes).

During the whole time we were in camp, we were ably assisted by our host, M. Alvado, who took a most intelligent interest in all our operations, and was ever ready and at hand to help us in any and every difficulty with which we were confronted. We take this opportunity of expressing our high appreciation of his services, and esteem for his character, and that of his wife, Madame Alvado. The latter attended most assiduously to all our personal wants, and in this way furthered most materially the objects of the expedition.

Observations made on the Day of the Eclipse.

Between 6 and 7 A.M. on May 28th I observed in the spectroscope the position angles and approximate heights of all the prominences then visible on the sun's limb. The results were then written out in accordance with a previously arranged code, and sent on to Zeralda to be telegraphed to Mr. A. C. D. Crommelin, at Algiers, for the use of intending observers of the coronal structure near to prominences.

The following table gives the position angles and heights observed:—

Position angle.	Solar latitude.	Approximate height Hα.
64°	+ 9°	50″
119	− 46	15
217	− 36	115/130
236	− 17	25
305	+ 52	20

The rest of the morning was devoted to final adjustments and rehearsals; cleaning all lenses and prisms, and in taking more photographs for focus in the 2-inch spectrograph. Soon after noon all slides were filled ready for the eclipse; and lastly, the 9-inch mirror and the cœlostat mirror were both dusted and carefully polished with rouge to remove all trace of tarnish.

Fifteen minutes before mid-eclipse the large spectrograph was slightly eadjusted for focus by observing with a lens the spectrum image of he diminishing crescent. This was effected without any difficulty or ncertainty.

I then attempted to focus the 2-inch spectrograph in the same way, ising the Fraunhofer lines near G, which were then rapidly becoming harply defined. As the last determination made photographically ppeared to be correct, I set it again to the same position.

Five minutes before mid-eclipse my brother wound up the cœlostat lock, and three minutes later I gave the order "Stand by."

The light waned rapidly, and I began the exposures at $4^h\ 16^m\ 58^s$. At $4^h\ 17^m\ 30^s$ I found it difficult to see the seconds hand of the chronoeter, and a few seconds later I opened for the 10-second exposure, iving at the same time the signal to expose the quartz spectrograph. The absence of any sound from the shutter warned us that the latter ad failed to act.

At $4^h\ 18^m$ I could again see the chronometer face clearly. I coninued the exposures according to the programme, finishing the last at $^h\ 18^m\ 18^s$.

A minute or two later, after removing all the plate holders from their slides, I observed the large prominences on the south-west limb in the spectroscope attached to the 3-inch telescope. They appeared, of course, exceedingly brilliant in the line $H\alpha$. Unfortunately, I was unable to make a critical examination of the spectrum, for at this time a crowd of sight-seers inundated the entire camp, and further observation for the time being was impossible.

Later, I observed the time of last contact with the spectroscope. This took place at

$$
\begin{array}{rrrl}
5^h & 21^m & 34^s & \text{per clock.} \\
 & & +58 & \text{assumed error of clock.} \\
\hline
5 & 22 & 32 & \text{G.M.T.}
\end{array}
$$

At this moment the moon's limb was seen as a black line projected on the chromosphere.

(4) *Results.*

Notwithstanding the fact that my station was outside the zone of total eclipse,* the photographs show that there was quite half a minute

* From the descriptions given us immediately after the eclipse by M. Alvado and others who undertook to determine accurately the duration of totality, it appeared certain that the photosphere never wholly disappeared, a small point of sunlight remaining visible at the moment of mid-eclipse. The edge of the moon's shadow was, moreover, clearly seen traversing the sea and the sand dunes a short distance north of our camp, w[illegible] a few hundred metres only.

available for obtaining good images of the flash spectrum. No. 9 spectrum, for instance, is one of the finest of the series, and shows about as many bright lines as the mid-eclipse photograph, yet it was exposed 15 seconds before mid-eclipse. Several other photographs taken earlier than No. 9 also show a large number of flash spectrum lines.

I think this result demonstrates the very great advantage gained at stations near the limit of total eclipse for studying this spectrum.

In cleaning the lens of the quartz spectrograph shortly before the eclipse, I unfortunately jammed the exposing shutter in such a way that it would not work at the critical time, and no photograph was obtained with this instrument.

Sixteen photographs were obtained with the 2-inch spectrograph, and sixteen with the reflecting spectrograph. The following table gives the approximate times of exposure, and the plates used in each instrument:—

Exposure No.	Approximate times.		Plates used.	
	Beginning.	Duration.	Reflecting spectrograph.	2-inch spectrograph.
	h. m. s.	sec.		
1	4 16 58	½	Sandell Triple	Sandell Perfect.
2	17 5	1	,, ,,	,, ,,
3	10	2	Sandell Perfect	,, ,,
4	14	2	,, ,,	,, ,,
5	18	2	Edwards's Ordinary Medium	,, ,,
6	23	2	,, ,,	Imperial Ordinary (Backed)
7	27	2	,, ,,	,, ,,
8	31	2	,, ,,	,, ,,
9	35	2	,, ,,	,, ,,
10	40	2	,, ,,	,, ,,
11	45	10	,, ,,	,, ,,
12	18 0	2	,, ,,	Sandell Triple.
13	4	2	Sandell Perfect	,, ,,
14	9	2	,, ,,	,, ,,
15	13	½	Sandell Triple	,, ,,
16	17	½	,, ,,	,, ,,

The images obtained with the 2-inch spectrograph are not in good focus. They are very dense in the region near G, but correctly exposed in the ultra-violet. The spectra extend from λ 3350 to λ 5100. Apparently the maladjustment of focus has produced a linear distortion of the images; and at the edges of several of the spectra, where the direction of the distortion coincides with the direction of the bright

nes, the focus appears to be quite perfect through the whole length of
ie spectrum.

This suggests that the lens, which was a thin one, was under some
rain in its cell, and it accounts for the difficulty experienced in find-
ig the true focus.

In the mid-eclipse photograph (No. 11) the bright lines are fairly
ell defined at the extreme end of the spectrum, and they can be
raced in this photograph to λ 3320. All the lines between λ 3340
nd λ 3500 can be identified with those shown on the best plate ob-
ained in 1898.

The following table gives the wave-lengths and identifications of
hese lines as determined for the spectrum obtained in India. In
dentifying the lines with the elements given in column 4, I received
reat assistance from Mr. L. E. Jewell, who also supplied me with
revised list of wave-length values for the solar lines given in
olumn 5.

The intensities (column 2) are estimated as follows:—

Lines just visible but extremely faint	=	0
The strongest lines in the spectrum	=	10

Wave-length (flash spectrum).	Intensity.	Character.	Element.	Wave-length. Rowland (solar spectrum).
3326±	2	Wave-lengths roughly estimated on photograph No. 11 of 1900.		
3330±	2			
3333±	1			
3335±	2			
3340·0	1½	First line on photograph No. 3 of 1898	Cr? *Ti*	3340·490
3342·3	2		Ti	42·012
3347·0	0	(One measure only)........	Ti	46·882
3349·4	4	Long	Ti	49·558
3354·0	2	Faintly extended	Sc	53·875
3358·5	2		Cr	58·649
3361·4	3½	Long	Ti	61·327
3368·3	3	Long	Cr	68·193
3373·0	4	Long	Ti	72·948
3380·4	3	Short.....................	Ti	80·424
3384·0	4	Long	Ti	83·892
3388·1	3	Long	Ti	87·988
3392·1	1½	(One measure only)........	Zr?	92·109
3394·7	3	Long	Ti	94·716
3399·3	1	Short.....................		
3403·45	3	Faintly extended	Cr	3403·494
3405·17	1	Short.....................	Co?	05·217
3407·32	1	Short.....................	Fe?	07·597
3408·97	3	Long	Cr	08·911
3410·24	1	Visible on south side only.		
3415·01	1	Visible on south side only ..	Ni	14·911
3421·42	3½	[illegible]	Cr	21·353
3422·94	3½		Cr	22·892

Wave-length (flash spectrum).	Intensity.	Character.	Element.	Wave-length, Rowland (solar spectrum).
3425·46	0	One measure only; very short.		
3426·97	0			
3428·73	0			
3430·61	1	Short	Zr?	3430·671
3433·54	4	Long	*Cr*, Ni	33·453 33·715
3438·40	2	Short	Zr?	38·376
3440·93	3	Faintly extended	Fe, Fe	40·762 41·155
3442·24	4	Long	..	42·112
3444·39	3	Faintly extended	Ti	44·467
3446·34	2	Ill-defined	Ni	46·406
3452·86	2		Ni	53·039
3456·55	2	Ill-defined; short	Ti	56·528
3458·58	1		Ni	58·601
3460·53	3	Long	Mn	60·460
3461·68	2	Faintly extended	Ti, Ni	61·633 61·801
3463·05	1	Interrupted; very short	Co	62·950
3464·32	1	Visible on continuous spectrum only.	Sr?	64·608
3465·87	2	Very faintly extended	Co, Fe	65·900 66·015
3467·46	0			
3468·72	0	.. .. ..	Fe	68·821
3471·33	1	Equal pair, short, and interrupted		
3472·58	1		Ni	72·680
3474·28	3	Long	Mn	74·287
3475·67	2	Short	Fe	75·594
3477·26	3	Long	Ti	77·323
3479·48	1½	Ill-defined; short	Zr?	79·531
3481·20	1½		Zr?	81·302
3483·08	3	Long	Mn	83·047
3488·85	3		Mn	88·817
3491·16	3		Ti	91·195
3493·22	2	Ill-defined	*Ni*, Fe	93·114 93·618
3494·60	1	Short.		
3496·17	3	Long.		
3497·82	2	Short.		
3499·14	0	Interrupted.		
3500·45	1	Short.		
3502·30	0	(One measure only)	Co	3502·394
3505·06	3½	Long; equal pair	Ti	05·036
3510·96	3½		Ti	10·985

In column 4 the predominating element in a group is put in italics.

The sixteen images of the cusp and flash spectra obtained with the reflecting spectrograph are in good focus throughout.* Each spectrum

* The very strong chromosphere arcs, such as H and K, show a faint coma on the more refrangible side. This has since been traced to slight irregular refraction at the base of the 60° prism. The fault is, however, too slight to appreciably affect the definition of any but the strongest lines.

is 8 inches long, and extends from λ 350 to λ 510. The width corresponding to the sun's diameter is 0·68 inch.

The finer flash spectrum lines in many of the photographs are particularly well defined in the ultra-violet.

The first four photographs of the series are much over-exposed and fogged, and only the stronger chromosphere arcs are visible at the edge of the continuous spectrum. In the succeeding images, the sky illumination becoming much diminished, the bright lines show up clearly on a light background.

In No. 9 the flash spectrum is fully developed in a rift in the continuous spectrum. This rift extends from position angle 140° to 148°, and includes a region between 67° and 75° south latitude. The bright lines crossing the rift are beautifully defined throughout the spectrum, and in the ultra violet they can be traced nearly as far as the continuous spectrum. The Fraunhofer lines are well defined upon the continuous spectrum, where the latter has not been over-exposed, and the whole spectrum in the ultra-violet is a mixture of bright and dark lines.

Accurate determinations of wave-length will result from the measurement of this negative.

No. 11. This was exposed for 10 seconds at the greatest phase of the eclipse. The continuous spectrum is broken up into five narrow bands, and the flash spectrum lines form long arcs crossing the bands. Most of these arcs extend over nearly 80° of the limb, and cover the entire south polar region, from latitude −75° on the east side to latitude −28° on the west.

The bright lines on this negative are more strongly impressed than on any of the others, and they can be clearly traced up to the end of the continuous spectrum at λ 350. The dark lines of the Fraunhofer spectrum are still traceable on the narrow strips of continuous spectrum.

This negative will give good wave-length determinations for all the finer lines between λ 350 and λ 510.

Good images of the flash spectrum are also impressed on photographs Nos. 10, 12, and 13.

General Conclusions.

(1) In its main features the flash spectrum at the south pole of the sun is the same as in low latitudes.

(2) No essential change is shown after an interval of four years; the spectra photographed by Shackleton, in 1896, and those obtained in 1898 and 1900, all appear to be identical so far as it has been possible to compare them.

(3) The flash spectrum, therefore, is probably as constant a feature of the solar surface as is the Fraunhofer spectrum.

With regard to instruments, the reflecting prismatic camera has proved to be a most efficient form of spectrograph for eclipse work.

The uniform focus over the entire range of spectrum, and the facility with which the adjustment for focus can be effected, are advantages which those who have worked with prismatic cameras will appreciate.

Another important advantage in the use of the reflector is the proximity of the exposing shutter to the plate holder, both of which can easily be controlled by one person. There is no signalling between the man at the plates and the man at the shutter.

There is again the advantage that there is no selective absorption of ultra-violet rays which occurs in lenses, and if the mirror is freshly polished there is no selective reflection for any of the rays which can be photographed.

In concluding, I have to acknowledge my great indebtedness to my brother for his untiring devotion to the interests of the expedition throughout. In all the negotiations necessary on arrival in the country he took a leading part, and was successful in obtaining the goodwill of every person with whom we came in contact.

The fine series of photographs which we obtained bear witness to his skill in carrying out, to the letter, the somewhat troublesome arrangements which I had planned for erecting and adjusting the instruments.

"Preliminary Note on Observations of the Total Solar Eclipse of 1900 May 28, made at Santa Pola (Casa del Pleito), Spain." By Ralph Copeland, Ph.D., F.R.A.S., F.R.S.E.—Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received October 1, 1900.

I had again the honour of being nominated one of the observers for the Joint Eclipse Committee, the station allotted to me being at Santa Pola, on the south-east coast of Spain.

On the 9th May I left Edinburgh, and sailed from Tilbury on the 11th in the Orient steamship "Oruba," accompanied by Mr. Thomas Heath, First Assistant at the Edinburgh Royal Observatory, who was going to Santa Pola to observe the eclipse on behalf of the Royal Society of Edinburgh.

My instrumental outfit had preceded me under the care of Mr. James McPherson, the experienced mechanician of our Edinburgh observatory. This outfit comprised the 40-foot horizontal telescope of 4-inch aperture previously used in India and Norway, together with a small Iceland spar and quartz prismatic camera, with an effective aperture of 1·8 inch.

At St. Pancras Station I had the pleasure of joining Lockyer and his party, who, like ourselves, were bound fo

Early on the 16th we reached Gibraltar, where we another member of our Edinburgh party, Mr. Franklin- Machrihanish, who had most thoughtfully arranged for th all our eclipse apparatus from the "Oruba" to H.M.S. which the Admiralty had generously placed at the disposal Committee. We were most cordially welcomed on board th by Captain Tisdall, who introduced us to his officers, and a our most comfortable quarters.

The few days spent on board the "Theseus" passed mo With the greatest interest we followed the various forms were greatly struck by the promptitude and precision with order was carried out.

On landing at Santa Pola on the afternoon of the 1 received with the utmost courtesy by the Alcalde and o authorities, who at once assured us of all possible assis urtherance of our work. The interchange of courtesies be at once proceeded to the camp already laid out for Sir Norm party. Abundant space had been left for the installation ratus, but on closer examination of the ground we found th light and sandy to afford the firm foundation required b instruments. We had therefore to select another site. Th in the upper part of the town, in a barley-field, from which been gathered a few days before. Here the solid rock, cove a thin layer of soil, afforded an ideal foundation for all ou while the neighbouring walls or houses protected the sit prevailing winds without unduly obstructing the view.

To the south-east of the selected spot stood a large chanced to be vacant in consequence of a law suit, and w called "La Casa del Pleito." This barn was allotted to us obliging Alcalde, and gave the name to our station. It se threefold capacity of a store-place for our empty boxes, a p laboratory, and a most welcome retreat from the burning noonday sun.

While our instruments were being landed and carted morning of the 18th, we commenced laying out and pre necessary foundations for them. In this, as in all our wor most efficiently helped by a detachment of junior officers an the "Theseus."

For the first few days there was a good deal of cloud, well as by day, and it was only with difficulty that the exa tions requisite for setting up the 40-foot were secured.

Saturday, the 19th, was a red-letter day for us, as well countrymen throughout the world. W... his usual thoug

Mr. Franklin-Adams, before leaving England, had arranged that a concise daily telegram should be sent to him giving the latest war news. These telegrams were at once communicated to both camps as well as to the "Theseus," and it is needless to say with what keen interest they were received and discussed. We were preparing for lunch at the comfortable little restaurant where we lodged when the telegram announcing the relief of Mafeking was received. Immediately we all rushed into the entrance hall, where we gave three hearty British cheers, greatly to the astonishment of our Spanish friends, who were quite at a loss to understand what all the cheering and excitement meant.

By Monday the 21st all our heavier concrete foundations were finished, and we had a clear week in which to adjust and test our appliances. The weather had also become much clearer, particularly in the afternoon, when it was important to check the final adjustments of the long telescope at the hour corresponding to that of the eclipse. Eventually all the adjustments were completed and tested by the 27th, on the afternoon of which day we had the satisfaction of seeing the sun's image traverse the plate-holder of the 40-foot precisely at the computed rate, and at the exact distance from the centre line corresponding to the sun's declination at the time.

On the 26th we received a visit from the Civil Governor of the Province of Alicante, who was desirous of seeing our apparatus and satisfying himself that everything possible was being done for our comfort and convenience. On the same day a party of French astronomers came over from Elche to see our camp and compare notes. We much regretted that time did not permit our returning their friendly visit.

Meanwhile, Mr. Heath and Mr. Franklin-Adams had erected the equatorial stands to carry their apparatus. Mr. Heath was provided with a 6-inch photo-visual telescope by T. Cooke and Sons, arranged to photograph the corona in the primary focal plane; while Mr. Franklin-Adams' equipment consisted of a number of cameras, several of them of large aperture, designed for obtaining pictures of the coronal rays and the sun's surroundings generally. He had also several very accurate thermometers mounted on a suitable screen.

The exact duties of each member of the camp were repeatedly rehearsed in accordance with the beats of a metronome, the indications of which were shouted out by a seaman on the plan devised by Sir Norman Lockyer for regulating the numerous operations at his camp. As most of the observers had already practised at their respective instruments, even the first general rehearsal went off much better than we could have expected. The whole credit of this is due to our naval assistants, who, from being trained to act promptly and in concert, readily appreciated the exact nature of the new duties entrusted to them.

...owed to come. On the
somewhat farther back at th

The weather on the mome
desire. With the greatest ca
of our barn had been smooth
expanse some 30 feet in widtl
the shadow bands. The azimu
and as mid-totality occurred ir
was very favourable for the ob
a white screen some 14 feet s
northern end of the wall, and
enclosed, thereby giving three
might be seen. Two officers
previously had practised mark
bands, were entrusted with the d
appeared on the white surfaces
attached to long poles, and witl
beginning of totality and red fo

I undertook to observe the f
2 inches aperture.

This occurred 10^s·4 before th
caused no surprise, as the moon's
contact, and there was the chanc
out a second or two. In view
no photographs of the partial ...

I have ...

e the signal "Start the clock" to McPherson, who was in the dark
m of the 40-foot. At this moment Mr. Franklin-Adams gave a few
kes on a large bell, and called out "*Silencio!*" I must here say
t this call was immediately obeyed in the most courteous way by
assembled crowds, who maintained a perfect silence until the
portant phase was over.

One minute before totality, at the signal "Chronograph," McPherson
gistered the position of the moving plate-holder. Sixteen seconds
fore totality, when, according to Mr. Fowler's computation, the
minishing crescent should subtend an arc of 90°, I gave the signal
Stand by;" five seconds before totality, corresponding to 55° of a
escent, the signal "Ready" was called, and at the disappearance of
e last glimpse of sunlight I gave the final signal of "Go!"

From this moment the sailor in charge of the metronome announced
ery fifth second during the first minute, and then every second until
e seventy-fifth, when he called "Stop!"

One minute and twenty-four seconds after the signal, I gave to
cPherson the final signal "Chronograph," which he again recorded
the moving plate-holder, assuring himself at the same time that it
s still moving at the regular speed. While I was giving the earlier
nals just mentioned, I noticed a very interesting feature in the
ninishing crescent. When the luminous crescent was reduced to a
re line, an exceptionally brilliant bead of light became detached
m the rest, continuing to shine like a bright star for perhaps four or
e seconds, and probably disappearing nearly at the same time as the
t of the crescent. It was doubtless due either to the passage of the
nlight through a very deep valley on the moon's limb or to the inter-
ption of the crescent by a high range of lunar mountains. What-
er its origin it presented an extreme case of the well-known phe-
menon of "Baily's Beads."

What struck me most, both in the late eclipse and in that of 1898,
s the sudden transition from the swiftly changing phenomena
tendant on the disappearance of sunlight to the steady unvarying
pect of the corona. During the last few minutes of the partial phase
l the phenomena are in a state of rapid change—the light decreases
a swift geometrical ratio, the last shred of the sun's limb disappears,
e prominences burst into view, and all at once the corona stands
fore one fixed and relatively unchanging during the whole of
tality.

The corona, as seen with the naked eye, presented a striking
semblance to the pictures of the corona of 1878. Below was a broad
uble streamer, like the outspread tail of a dove, symmetrical to the
n's equator, while opposite to this was a single large pointed streamer
volved in a much fainter dove-tail symmetrical to the one below.
he spectrum shown by an excellent direct-vision prism about mid-

totality struck me as being very continuous, for I did not see the K 1474 ring. In common with all other observers, I was struck by the extreme brightness and the red colour of Mercury some 2½° preceding the Sun, while near the zenith Venus blazed in the purest white.

Turning to the photographic results, three successful negatives of the prominences and the corona were obtained with the 40-foot, with exposures of $5^s \cdot 0$, $18^s \cdot 6$, and $3^s \cdot 0$ respectively. On the whole, the long exposure gives the best picture; in the original negative the light of the great equatorial streamers can be traced to a distance of about one solar diameter from the moon's limb, while the detail of the shorter streamers is shown with considerable precision. The short exposures naturally bring out the shorter rays that are to some extent lost in the brightness due to the long exposure.

There are also twenty-four spectrograms taken with a direct-vision prism drawn in front of the object glass of the 40-foot. Of these, two groups of ten each were secured, one set as totality was coming on and the other immediately after it had ended. They were taken on plates measuring 8 inches by 16 inches, so arranged as to be moved transversely in the plate-holder between each exposure. The "height" of each spectrogram is 0·3 inch, while an interval of ½ inch is allowed between the different pictures. The remaining four spectrograms were taken after totality with the 40-foot acting as a prismatic camera. The two earlier ones show H, K and other lines extending beyond the continuous spectrum, while the two last are of little interest except for finding how long after the end of totality it is possible to obtain useful spectrograms.

In developing these plates, and in making the copies and slides* from them, we had the advantage of the skilful assistance of Mr. John Banks, photographer, of Edinburgh.

McPherson's position inside the dark room of the 40-foot gave him the unique opportunity of watching the actual image of the sun's appendages as it imprinted itself on the sensitive films. At the time of making the exposure of nearly nineteen seconds at mid-totality he describes the picture as comparatively dark—very little of the corona being visible; the larger prominences were, however, noticed, although they were not nearly so bright as afterwards. In the last exposure, near the end of totality, the prominences appeared of a bright flaming red colour, and the picture on the plate was altogether a splendid sight. Mr. McPherson was watching the prominences under the impression that there were still five seconds to spare, as the timekeeper at the metronome was counting seventy, and we expected the eclipse to last seventy-five seconds, when all at once a sudden increase

* The best of these slides, as well as contact copies of the larger negatives, were exhibited at the meeting.

of brightness took place on the moon's limb—white light seeming to curl over the edge of the moon's disc. Immediately concluding that the total phase was all but over, he let go the cord and closed the shutter. When working with the prism the exposures were far too short to permit of seeing the images.

The spar camera was in charge of William Slaughter, petty officer of the "Theseus"; it could not possibly have been in better hands, for in spite of the lightness of the 3-inch equatorial mounting and the delicate clock movement by which it was carried, he exposed all his plates without deranging the instrument in the slightest degree. Six spectrograms were obtained in all, several of which contain many ultra-violet lines belonging to the chromosphere, or possibly to the lower layers of the corona.

Pending the presentation of the report on the shadow-bands which is in my hands, but which I should like to supplement by a short computation, I may say that the two officers of the "Theseus," Mr. Green and Mr. Alexander, succeeded in marking the course of the shadow-bands on the vertical wall both at the beginning and at the end of the total phase. As totality came on, the faint rippling bands moved to the right upwards, the direction of motion making an angle of 20° to 30° with the vertical; at the end of the dark phase the motion was in the opposite direction—to the left downwards—the motion in both cases being at right angles to the lines. The lines appeared in short wavy fragments. Quite at the last, a little after the main body of the lines had disappeared, there came a solitary thicker line, more distinct than the rest, and moving less rapidly in a direction inclined 47° to the vertical, but otherwise in the same general direction as the rest of the lines. The wall was photographed, but although the negative shows the red lines distinctly enough, the full blue colour used at the beginning of totality, can scarcely be seen in the photograph. No bands were satisfactorily made out on either of the two other planes.

The warmest thanks of our party are due—to the Admiralty for all the assistance given to us; to the officers and crew of H.M.S. "Theseus" for their hearty co-operation, which contributed so largely to the success of our endeavours; to the British Vice-Consul at Alicante; to the Spanish authorities and to our Santa Pola friends for their untiring courtesy and kindness; and to the "Orient" Steamship Company for their very liberal concession in carrying our bulky impedimenta practically free of cost.

"Total Eclipse of the Sun, 1900, May 28. Preliminary Account of the Observations made at Ovar, Portugal." By W. H. M. CHRISTIE, C.B., M.A., F.R.S., Astronomer Royal, and F. W. DYSON, M.A., Sec. R.A.S. Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received October 18, 1900.

[PLATES 21—24.]

I. *General Arrangements.*

An expedition to observe the total solar eclipse of May 28 having been sanctioned by the Admiralty, it was arranged, in concert with the Joint Permanent Eclipse Committee, that the Royal Observatory party should take photographs of the corona on a large scale for structural detail, and on a smaller scale for the coronal streamers, and should also photograph the spectrum of the "flash" and of the corona. The programme thus naturally divided itself into two parts, Mr. Christie, assisted by Mr. Davidson, taking charge of the first part, and Mr. Dyson of the second.

The party are much indebted to the Portuguese Government for the liberal arrangements made for the conveyance of the observers and their instruments in Portugal free of all charge to and from their observing station at Ovar, and for the great assistance rendered in erecting the instruments, and for a daily time-signal from the Lisbon Observatory direct to the observing station.

They are also indebted to Mr. Frank Rawes, of Oporto, for making all arrangements for a suitable observing station at Ovar, and for much thoughtful provision for the comfort and convenience of the observers.

The party further received valuable assistance from Mr. J. J. Atkinson, who went with them from England, and from Mr. Arthur Berry, who joined them in Portugal on May 20; they readily joined in all the work of the expedition, such as the erection of huts, instruments, &c. The party are also indebted to them, and to Mrs. Kennedy and to Mr. Rawes, for assistance in the observations on the day of the eclipse.

Itinerary.—The observing huts and instruments were sent to Southampton on May 8, with the exception of the 16-inch cœlostat mirror, and two boxes of photographic plates which were taken with the observers' personal baggage. The observers left Greenwich on the morning of Friday, May 11, sailing from Southampton by the Royal Mail steamship "Clyde," and reaching Lisbon about noon on May 14. After an interesting visit to the Royal Observatory at Tapada, Lisbon, on May 15, the observers left for Ovar on the evening of May 16, and arrived there on the morning of Thursday, May 17.

They left Ovar for Lisbon on Tuesday evening, May 29, the day after the eclipse, and left for England by the Royal Mail steamship "Magdalena," on Friday, June 1, reaching Southampton on June 4, and Greenwich on June 5. While at Lisbon, the Astronomer Royal had the honour of an audience with His Majesty the King of Portugal.

Station.—The station chosen was at Ovar, in Portugal, near the extreme westerly point of the line of totality in Europe, having the advantage of the longest totality.

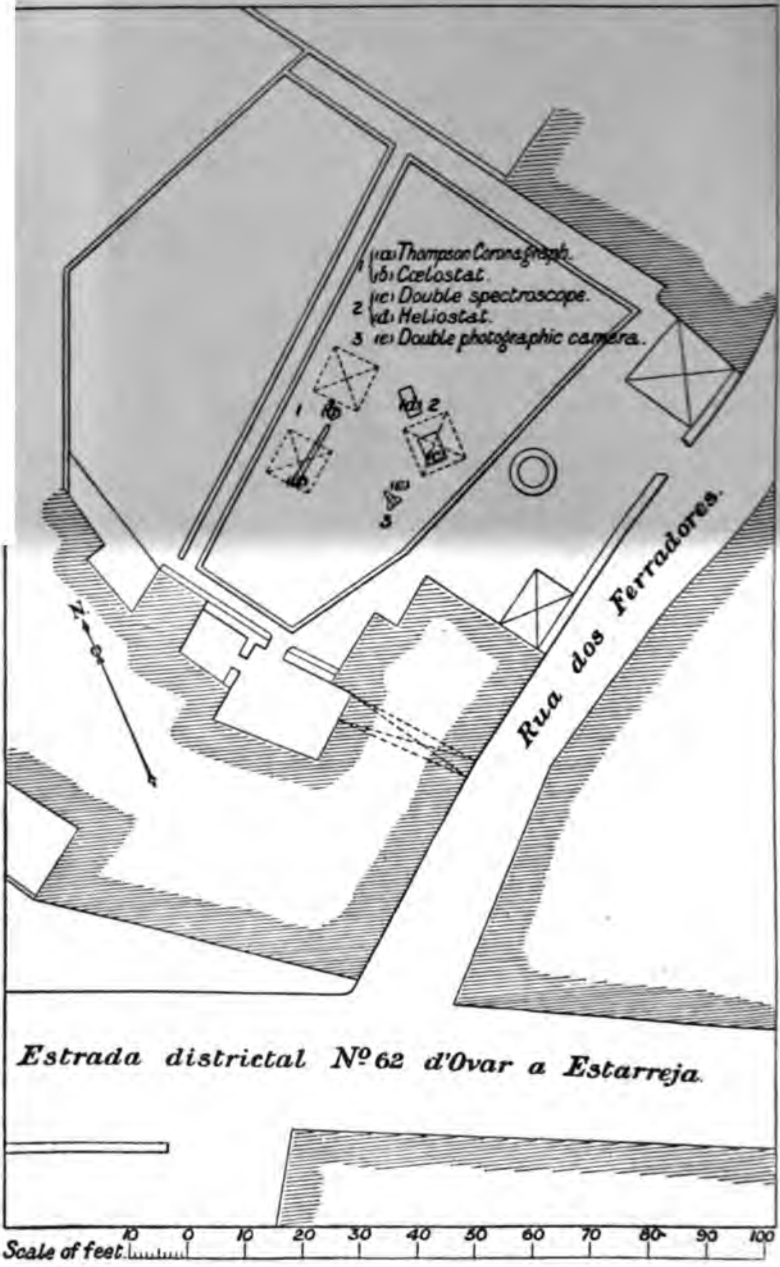
Ovar is a town about twenty miles south of Oporto, on the railway line to Lisbon; it is situated on a sandy plain, which stretches to the sea, the nearest point of the coast being about three miles distant. The meteorological conditions of this station proved to be good, the sky being clear on eight of the thirteen days during which the observers were there.

The station occupied by the observers was the garden of Mr. Silveiro's house; its position, taken from the Ordnance map in conjunction with plans of the town, furnished by the Public Works Department, is lat. 40° 51′ 30″ N., and long. 8° 37′ 3″ W., and is about $1\frac{3}{8}$ m. from the central line of the eclipse.

Erection and Disposition of Huts and Instruments.—It was found on arrival at the station that the loose sandy soil reached to a depth of at least 18 feet, thus rendering the erection of concrete or masonry piers unsuitable, as well as impracticable. The ground was accordingly cleared on May 17, the day of arrival, and thoroughly rammed; the wet weather which had prevailed previous to the arrival, rendered this the more effectual. On the same day the instruments and materials for the huts were brought from the railway station, half a mile away, in ox-waggons, and partially unpacked. The arrangement of instruments and huts was also roughly marked out.

On the next day, May 18, the huts to cover the instruments were erected, and boxes filled with stones, on which to mount them, were placed in position. The huts were light wooden frames, covered with Willesden waterproof canvas; they were fitted together at Greenwich before starting, and the woodwork marked, so that they were readily fixed up. There were three huts exactly alike structurally, each being 8 feet square and 8 feet high, rising to 10 feet at the gable; the canvas was thrown over the top and sides in two lengths, and tacked down to the woodwork; the ends of the huts were arranged with panels when necessary, which could be removed as required. Two of these huts, without any canvas at the adjacent ends, were bolted together, forming one large hut 16 feet by 8 feet, to cover the coronagraph and 16-inch cœlostat. For observation the bolts were removed, and the hut over the cœlostat moved back a few feet. The spectrographs were in the third hut, and the heliostat supplying them was outside the hut,

PLAN OF ECLIPSE STATION AT OVAR, 1900, MAY 28.



and provided with a light canvas cover when not in use. The equatorial with the double tube for the small-scale photographs of the corona was covered with a sheet of waterproof canvas when not in use. The arrangement of the different huts and instruments is shown in the accompanying plan.

The instruments were all erected on May 19, the observers thus having a clear week to adjust them, and to rehearse the observations.

Personnel.—The following list gives the names of those who took part in the observations :—

W. H. M. Christie :—Thompson coronagraph. Large scale photographs of corona.

F. W. Dyson :—Double photographic spectroscope. Spectrum of "flash" and of corona.

C. Davidson :—Double camera. Small scale photographs of corona to show extension.

J. J. Atkinson :—Assisted Mr. Dyson, moving plate-holders and changing plates for the flint prism spectroscope.

A. Berry :—Counted seconds for first half of totality, and then set the heliostat for second contact.

Mrs. Kennedy :—Counted seconds for second half of totality.

Frank Rawes :—Read thermometers during eclipse.

Four Portuguese Soldiers :—Handed plate-holders during totality for Mr. Christie and Mr. Davidson respectively.

The following was the method of procedure, which was carefully rehearsed on several occasions previously. The observers were stationed at their instruments, and Mr. Christie watched the diminishing crescent of the sun on the ground glass of his coronagraph. He had a paper scale on which the lengths of the crescent were marked, computed for the intervals 3 mins., 2 mins., 1 min., 45 secs., 30 secs., 25 secs., 20 secs., 15 secs., 10 secs., before totality ; at 15 secs. the length of the crescent was 2·64 inches, and at 10 secs. before totality 2·30 inches. Having previously given the signal, "Get Ready," Mr. Christie called out "Ten" at 10 secs. before totality, which was the signal to Mr. Dyson to begin the exposures for the "flash." At totality Mr. Christie again gave the signal (the monosyllable "Tup" was used) and Mr. Berry started a metronome which had been carefully rated to give seconds, and proceeded to count up to 50. Mrs. Kennedy took up the count at 51, and continued counting as far as 100, which had been estimated as 10 secs. beyond totality. While the count was proceeding, exposures at the several instruments were made, as described in the separate reports

The Day of the Eclipse.—It was quite clear in the early morning, but some light cirrus clouds collected later, causing the observers some apprehensions. There was some light cloud in the sky during totality,

but there is no reason to suppose that it interfered seriously with the observations.

The first contact occurred at 2^h 6^m 20^s Lisbon Mean Time, and was observed by Mr. Christie on the ground glass of the coronagraph. The time of commencement of the total phase was not accurately noted; the duration was observed (by means of a stop-watch) and found to be $84\frac{1}{2}$ secs., during which the programme detailed below was carried out. After totality photographs were taken for orientation. The fourth contact was at 4^h 36^m 13^s Lisbon Mean Time. There was a good deal of light during totality, the diminution of light being similar to that occurring during a heavy thunderstorm in summer. The temperature fell about 8° during the eclipse.

During totality Mercury and Venus were seen, Mercury especially being very brilliant. The observers had not much opportunity of observing the attendant phenomena of the eclipse, and with the assistance which was kindly given them were only just able to provide adequately for the working of the instruments.

II. *Photographs of the Corona.*

The programme of observations was composed of two distinct parts:—

(1.) Photographs of the corona on a large scale to show structural detail.

(2.) Photographs on a smaller scale with rapid lenses to show the coronal streamers with the greatest possible extension.

(1) *Large-scale Photographs.*

(These were taken by Mr. W. H. M. Christie.)

The instrument used for (1) was the Thompson photographic telescope, with object-glass of 9 inches aperture and 8 feet 6 inches focal length, belonging to the Royal Observatory, in combination with a concave telephoto lens by Dallmeyer, of 4 inches aperture and 16 inches focus, fitted as a secondary magnifier, to give an image of the Sun 4 inches in diameter, with a field (for full pencils) of 14 inches diameter. The total length of the coronagraph was 12 feet—the equivalent focal length being about 36 feet. A cœlostat with 16-inch plane mirror (made by Dr. Common) was employed to reflect the rays into the coronagraph, which was mounted (on boxes filled with stones) so as to point to the mirror at an angle of depression of about 5°, and at an azimuth of about 56° West of South for the day of the eclipse. The camera was furnished with five plate-holders to take 15 × 15 inch plates or for the shorter exposures 12 × 10 inch plates in a carrier.

The five slides for photographs of the corona during totality were

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exposed as below, the exposures being given by the observer with the exposing shutter of the plate-holder, and the times noted by him, counting from the commencement of totality.

No.	Exposure. Beginning.	End.	Duration.	Plate.	
1......	7s	$8\frac{1}{2}$s	$1\frac{1}{2}$s	Lantern	12 in. × 10 in.
2......	16	22	6	Empress	12 " × 10 "
3......	30	50	20	Sandell's Triple-coated	15 " × 15 "
4......	56	68	12	Special Rapid	15 " × 15 "
5......	76	$78\frac{1}{2}$	$2\frac{1}{2}$	Lantern	12 " × 10 "

As soon as possible after totality a second plate was put in No. 5 plate-holder, and exposed twice on the sun for orientation (with driving clock stopped for 3 min. between), the exposure being as short as possible ($\frac{1}{3}$ to $\frac{1}{2}$ sec.), and the aperture reduced to 2 inches.

"Abney squares" were put on Nos. 1, 3 (twice), and 5, after return home.

No. 1	300s	exposure at	5	ft. to standard	candle.
No. 3 ...	5s and 30	"	5	"	"
No. 5	300	"	3	"	"

The plates were all developed after return home, hydroquinone dilute being used. Nos. 1 and 5 unfortunately blistered badly in development, especially No. 1, though every care was taken, the developer being at a temperature of 60°. It is to be remarked that other plates developed at the same time under precisely similar conditions were free from blistering. No. 2 is to a certain extent disfigured with spots on the plate, which, however, do not materially interfere with the coronal detail.

No. 4 shows fine detail in the polar plumes and coronal streamers extending to nearly a diameter of the Sun from the limb. No. 3 shows nearly the same.

No. 5 shows very fine detail in the prominences in the S.W. quadrant, with gradation of brightness merging into the coronal structure close to the limb, thus showing a continuity between the two phenomena, and affording fresh evidence of the association between coronal streamers and prominences, which was indicated in the photographs of the 1898 eclipse.

It should be mentioned that the coronagraph was carefully focussed in the same manner as for the eclipses of 1896 and 1898,* by means of the image of an object (gauze net) in the plane of the plate reflected from the plane mirror of the cœlostat. The focus was thus obtained with great accuracy after two or three trials, and it was found that the field was remarkably flat.

* 'Monthly Notices R.A S.,' vol. 57, p. 105; 'Roy. Soc. Proc.,' vol. 64, p. 8.

(2) *Small-scale Photographs to show Extension of the Corona.*

(These were taken by Mr. C. Davidson.)

The double camera, used in former eclipses, was adapted to carry a Dallmeyer rapid rectilinear lens of 4 inches aperture and 34 inches focus, working at f/8 in one-half of the tube. This lens was lent by the Royal Astronomical Society, the two halves, which had been used separately in former eclipses since 1882, having been reunited for the present eclipse.

In the other half of the camera tube there was mounted a new "Unar" lens by Ross, of 2·4 inches aperture and 12 inches focus, working at f/5.

Four plate-holders, each taking a pair of 16 × 16 cm. plates side by side were used during totality, both plates being exposed by a quarter turn of a shutter. A fifth plate-holder was used to obtain double images of the Sun for orientation as soon as practicable after totality.

The double camera was mounted on the equatorial stand of one of the Dallmeyer photo-heliographs, originally made for the Transit of Venus 1874, the middle section of the stand being removed to make it more handy.

Both lenses were carefully focussed on star-fields, the final adjustment being made by inserting thin metal rings beneath the flange of the lens.

The four slides for photographs of extension of the corona were exposed as below, the exposures being noted by the observer, counting from the commencement of totality.

No.	Exposure. Begin-ning.	End.	Dura-tion.	Plate.
1......	3^s	8^s	5^s	Sandell Double-coated.
2......	18	48	30	„ Triple-coated.
3......	57	72	15	„ „
4......	80	83	3	Empress.

Shortly after totality the fifth slide with Sandell double-coated plates was exposed three times on the Sun for orientation at intervals of $3\frac{1}{2}$ mins. with the driving clock stopped. In this case both lenses were stopped down to their smallest aperture, *i.e.*, f/64 for the "Unar" lens and f/44 for the Dallmeyer, and the exposure was as short as possible (about $\frac{1}{4}$ sec.).

"Abney squares" were put on Nos. 2 and 4 after return home.

No. 2 30 secs. exposure at 5 feet to standard candle.

No. 4 10 „ „ „ „

The photographs with short exposure No. 4—3 secs. are the most

ECLIPSE OF SUN. OVAR. 1900 MAY 28.

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Photograph of Corona, obtained with Dallmeyer rapid rectilinear lens of 4 inches aperture (enlarged 1½ times from photograph No. 1). [The planet Mercury is shown on the western side of the photograph.]

Photograph of Prominences in S.W. Quadrant (enlarged 2½ times from photograph No. 5, taken with the large coronagraph). [The spot with cross rays on the right-hand side is a defect in the photographic plate.]

successful, and show the greatest extension, that taken with the "Abney" lens showing rays which can be traced on the east side to a distance of more than 2° from Sun's centre, and on the west side to a distance of fully $1\frac{3}{4}$°. This is further than they could be traced visually under the atmospheric conditions at Ovar, where the observers traced them to a distance estimated at $\frac{2}{3}$ of distance of Mercury from centre, *i.e.*, $1\frac{1}{3}$°.

III. *The Spectroscopic Cameras.*

(By F. W. Dyson.)

Instruments.—The spectroscopes used were two kindly lent by Captain Hills, and employed by him in the Indian Eclipse of 1898, January 22. The details of their adjustments as used at Ovar are as follows:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke, achromatic, $4\frac{1}{2}$ in. aperture, 6 ft. $2\frac{1}{4}$ in. focus.	Single quartz lens, 5 in. aperture, 4 ft. $7\frac{3}{4}$ in. focus.
Collimator and camera lens	Single quartz lens, $2\frac{1}{2}$ in. aperture, 30 in. focus.	Single quartz lens, 3 in. aperture, 36 in. focus.
Slit	$1\frac{1}{2}$ in. by 0·0014 in.	2 in. by 0·0012 in.
Prisms	Two dense flint prisms of 60°, $4\frac{1}{2}$ in. base, $2\frac{1}{2}$ in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), $3\frac{1}{2}$ in. base, $2\frac{3}{4}$ in. height.
Prisms at minimum deviation for	H_γ (λ 4340).	H_ζ (λ 3889).

The width of the slits were adjusted by a method given by Mr. Newall. The third diffraction image of the slit, viewed by putting the eye near the position of the plate, was made to come on the edge of the object-glass by altering the width of the slit, and the slit left at this reading.

The length of the spectrum on the plate for spectroscope No. 1 was $3\frac{1}{4}$ inches from H_β (λ 4861) to K (λ 3934), and for spectroscope No. 2 $2\frac{1}{4}$ inches from λ 4100 to λ 3500.

Both spectroscopes were mounted horizontally, and were supplied with light by a heliostat furnished with a 12-inch flat mirror.

Erection and Adjustment of Instruments.—As the nature of the ground was unsuitable for brickwork or concrete piers, three of the boxes in which the instruments were carried were filled with stones and the

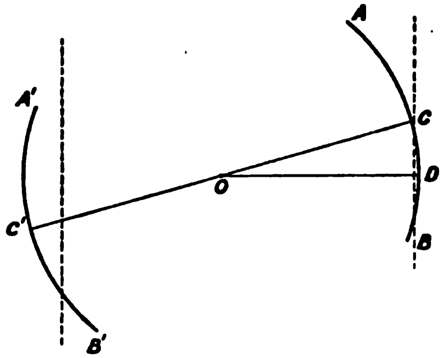
instruments erected on them. On one of these—a large clock case, 5 feet long, $2\frac{1}{2}$ feet broad, and $1\frac{1}{2}$ feet high—the heliostat was placed, a light wooden frame holding the two objectives. This was covered when not in use by Willesden canvas on a light wooden framework which could be readily lifted on and off. The spectroscopes stood on a mahogany table, 5 feet by 4 feet, which rested on the topmost of two boxes. The boxes were of such a height that the middle of the slits of the two spectroscopes were respectively half an inch below and half an inch above the centre of the mirror. This had to be arranged somewhat carefully, as a 5-inch and a $4\frac{1}{2}$-inch lens had to be supplied with light by a 12-inch mirror whose normal at the time of the eclipse was inclined more than 40° to the incident and reflected rays. The spectroscopes were in a hut, 8 feet square, made of Willesden canvas, facing north and south, and with the north side open when the instruments were in use.

The adjustment of the polar axis of the heliostat was made by means of an attached theodolite, the altitude of the axis being first set to the latitude, and the azimuth then adjusted by observing the sun's declination at different hour-angles from 9^h to 16^h. In this way the instrument was readily adjusted till the observed declinations of the sun agreed to within $2'$ with those of the Nautical Almanac throughout the above range of hour-angle. The stability of the mounting of the instrument on the sand was quite satisfactory, only very small changes in level occurring, and no perceptible changes in azimuth. The only difficulty experienced with the heliostat was in the driving, which is not very satisfactory at large azimuths.

Programme of Exposures.—The two spectroscopes were adjusted to be as nearly as possible on the sun's limb simultaneously, and the programme of exposures was the same for both. The cameras of the two spectroscopes were provided with rack movements, so that a number of exposures could be made on the same plate. A flap was arranged so that the exposures for both spectroscopes were made at the same time. The programme, as arranged with an expected duration of totality of 90 secs., was as follows :—

Ten exposures were made of 1 sec. duration beginning 10 secs. before totality at about 1 sec. apart for the spectrum of the "flash" at the beginning of totality. The plates were then changed, and at 20 secs. from the beginning of totality the plates were exposed for 50 secs., *i.e.*, till 70 secs. from the beginning of totality for the spectrum of the corona. The plates were again changed and the image on the slit moved by Mr. Berry by means of the slow motion of the heliostat, and ten exposures of 1 sec. duration, beginning at 80 secs. after first contact, were given for the spectrum of the "flash" at second contact. The conditions under which the "flash" was photographed, as determined by the circumstances of the eclipse at Ovar and

the instruments used, are shown in the accompanying diagram, whicl is enlarged about four times.



O is the centre of the sun's disc; AB is the bright arc as seei 10 secs. before totality, and is 70°. The centre of the arc, C, which i about 1° from the equator, is 16° above the point D where the arc i vertical and could be made to touch the slit. The slit, which is repre sented by dotted lines, cut the bright arc between C and D, the hori zontal distance between C and D being $\frac{1}{30}$th of an inch. The time fo the first exposure, viz., 10 secs. before totality, was given to th observers by the Astronomer Royal from the length of the rapidl diminishing arc as seen by him on the ground glass of the corono graph. This time appears to have been given correct to about 1 sec.

The position of the image on the slit was not changed for th spectrum of the corona, which was obtained near the point of secon contact.

For the "flash" at third contact the slow motion of the heliosta was used, making the sun's image travel in the direction OC of th diagram, the amount of the displacement being determined by watch ing the sun in the attached theodolite. The position of the sli relatively to the bright arc is shown in the second diagram; in thi case the slit was not nearly tangential to the sun's limb.

The photographic plates used were Ilford "Empress" for the firs "flash" photograph with the flint spectroscope and for both th "flash" photographs with the quartz. An Ilford "Ordinary" wa used for the second "flash" photograph with the flint. Cadett "Light ning plates" were used for both photographs of the corona spectrum.

Spectrum of the Sun's Limb.—The series of spectra of the limb shov a large number of lines, but they have not yet been examined in detail With the flint spectroscope, a spectrum is obtained extending fron F to K. This is good from F to *h*. With the quartz the spec trum reaches from *h* to λ 3300, and is in good definition to abou λ 3450. The photographs taken with the quartz spectroscope at th

beginning of totality are an interesting series. They show a long series of hydrogen lines (26 beginning at *h*), and a large number of iron and titanium lines. The difference in behaviour of these two metals is shown in a striking manner, the titanium lines, like the hydrogen lines, being bright in the whole series of photos. beginning 10 secs. before totality, while the iron lines are reversed in the earlier photographs. Titanium lines at wave-lengths 3685·30, 3761·46, and 3759·42 are specially bright. A reproduction is given of part of this series of photographs. (Plate 23).

The Corona Spectra.—Reproductions of these spectra are given in the accompanying plate (Plate 24). With the flint spectroscope a continuous spectrum is obtained from F to H. Eight bright lines are distinctly shown stretching right across the continuous spectrum, and several shorter lines in the densest part. The line 1474 K is not shown, probably because plates specially sensitive in the green were not used. The wave-lengths of the lines have not yet been determined. The positions of the corona lines are indicated on the plate and can be seen in the top band, though only faintly.

With the quartz spectroscope a continuous spectrum is shown which can be faintly traced as far as λ 3600. Strong bright lines are shown at λ 3987 and λ 3801.

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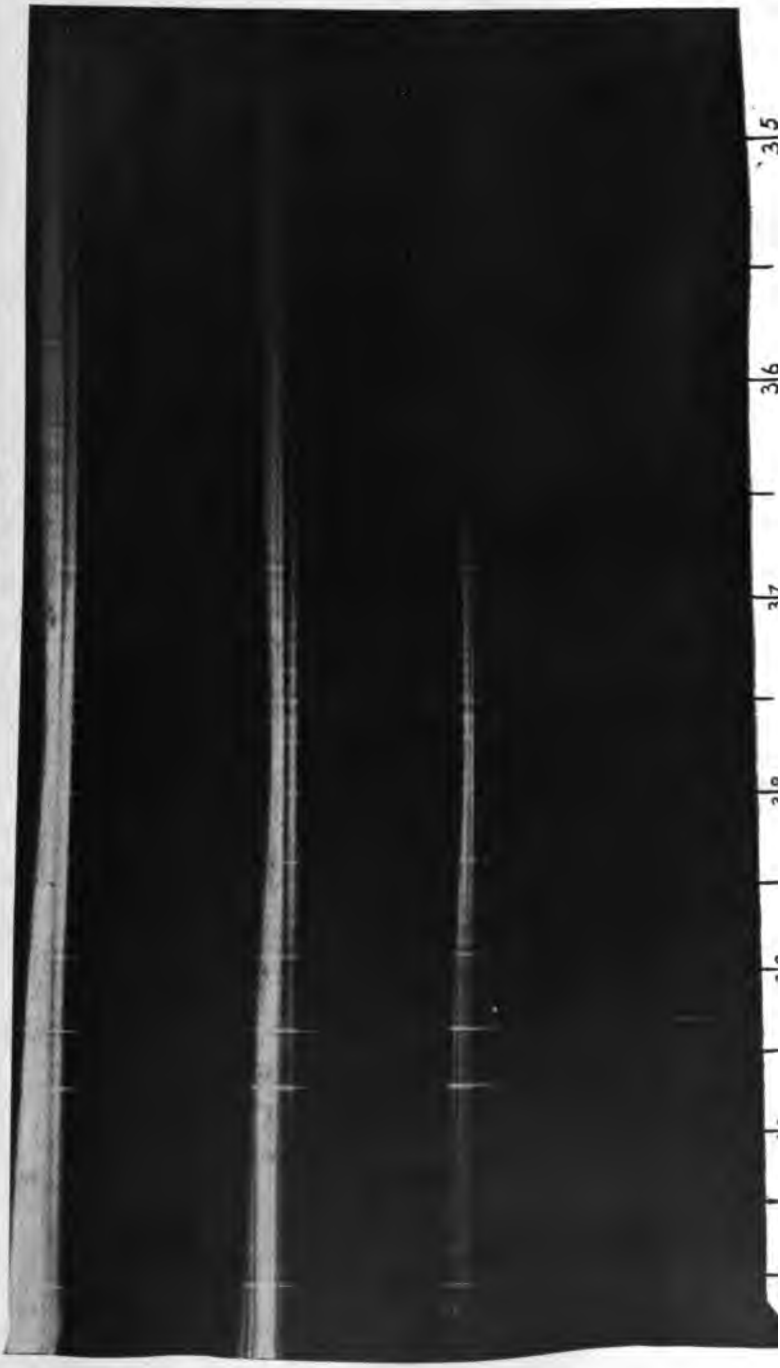
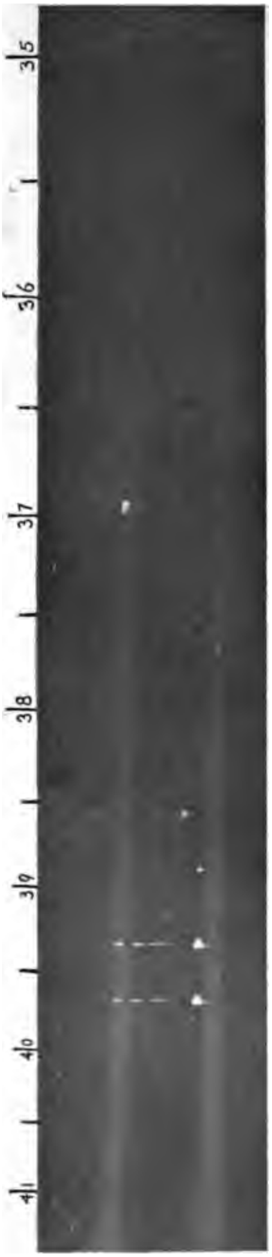
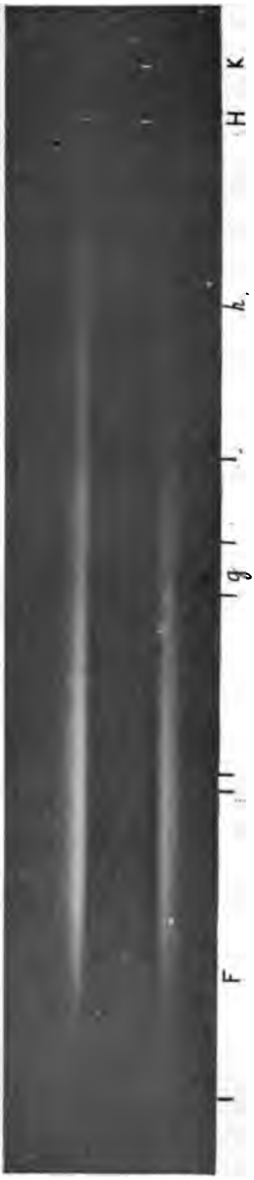


ECLIPSE OF SUN. OVAR. 1900 MAY 28.

ECLIPSE OF SUN. OVAR. 1900 MAY 28.



Spectrum of Corona, taken with the Quartz Spectroscope (enlarged 2¾ times).



Spectrum of Corona, obtained with Flint Spectroscope (enlarged 1¾ times).

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APPENDIX.

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Extra.

Note on the
New Star in the Constellation Perseus.

Note on the New Star in the Constellation Perse

By the Rev. W. R. WAUGH.

(Read Feb. 28th, 1901.)

THE astronomical world is much interested—we m almost say *excited*—by the somewhat su appearance of a new and bright star in the stellation Perseus. It is situated near the known variable star, Algol, north declina 43° 34min., and right ascension 3hr. 24min. 25 forming the apex of an acute triangle with A Persei and Beta Persei. Its magnitude is a that of an average first magnitude star. Its ti a steely blue. I estimate it as nearly as lustrous as Proc Its spectrum is solar and continuous. It is too earl determine whether bright lines are developed in its spect By whom it was first discovered has not been ascertai though it is probable that our American brethren will usual, be able to claim that honour, their vigilance as obse making it probable. No *Nova* (as new stars are gene designated) so large and of so striking an appearance been seen since Tycho Brahe discovered the very bright in the constellation Cassiopœia in the year 1572. I pos an average knowledge of that part of the stellar hea

NOVA PERSEI (10TH MARCH, 1901).
[Photographed by H. Ellis, Esq , F.R.A.S.]
Exposure, 110 minutes.

it having been assigned to me by Mr. Gore, the late Variable Star Director of the British Astronomical Association, in order to watch for variables and *Novea*, and I am quite sure that there was no star of sufficient brightness to attract attention in the early part of February. Hence it is fair to conclude that it has burst out suddenly in the sky.

The cause of these wonderful apparitions is an unsolved problem in astronomy. There are three leading conjectures that may be worth attention.

1st.—That they are the sudden condensation of nebulous matter, causing intense light and heat in the formation of a new sun, a new creation in fact.

2nd.—That they are the destruction of a sun and its planetary attendants by a vast conflagration, such as the predicted fate of our own system.

3rd.—That they are the result of a collision between two or more stellar bodies, the impact arising from the rapid motion of such developing intense heat, and brilliant light arising from the gaseous nature, or semi-gaseous nature, of such bodies, not necessarily light-generating prior to the impact. The large proportion of hydrogen known by the spectroscope to exist in half-formed suns gives some credibility to this theory, though there are many objections to this supposition, the chief being the electric propulsion inherent in gases or their compounds. Of course, it is presupposed that any or all of these causes are subject to the control or arrangement of the Supreme, according to laws at present unknown to us.

Any observations, however seemingly slight, will be welcome contributions to the solution of these intricate problems, and the members of the Dorset Field Club may assist if they will put their observations in a permanent form and forward them to Colonel Markwick, of the Ordnance Department at Devonport, Colonel Markwick being the present experienced Director of the Variable Star Section of the British Astronomical Association.

NOTE ON THE NEW STAR.

Tabular statement of light variations of Nova Persei, as given by observers at Kensington, communicated to the Royal Astronomical Society by Sir Norman Lockyer:—

1901.		
March	5th	2·7
„	6th	2·9
„	9th	3·5
„	10th	3·7
„	11th	4·0
„	12th	3·8
„	21st	4·2
„	22nd	—
„	23rd	4·2
„	24th	4·5
„	25th	5·5

The star has been long invisible to the unassisted eye, but its place is being carefully watched by many competent observers in hope of a possible revival.

Sir Norman Lockyer gives the following general description of its spectrum:—

"The photographs show that the bright hydrogen lines are successively feeble as the ultra violet is approached. The spectrum extends far into the ultra violet. Also, that there have been changes in the photographic spectrum."

The following metals are reported as being certainly detected:—Fe., Ti., Ce., Ca., Sr., and Se. The iron lines were very distinct. *Colour*—At discovery it was bluish white. During the period of decline it assumed a reddish hue. These changes in colour have been reported in the case of other Novea.

Full particulars of the spectrum are given by Sir Norman Lockyer in the "Monthly Notices" of the "Royal Astronomical Society, also by other observers.

It is hoped the discovery of Nova Persei by Dr. Anderson will induce others to watch for Novea.